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Welding Journal
VOLUME 20, No. 10
OCTOBER, 1941

Spot-Welding Control and Supervision*

By J. R. Fetcher†

Abstract

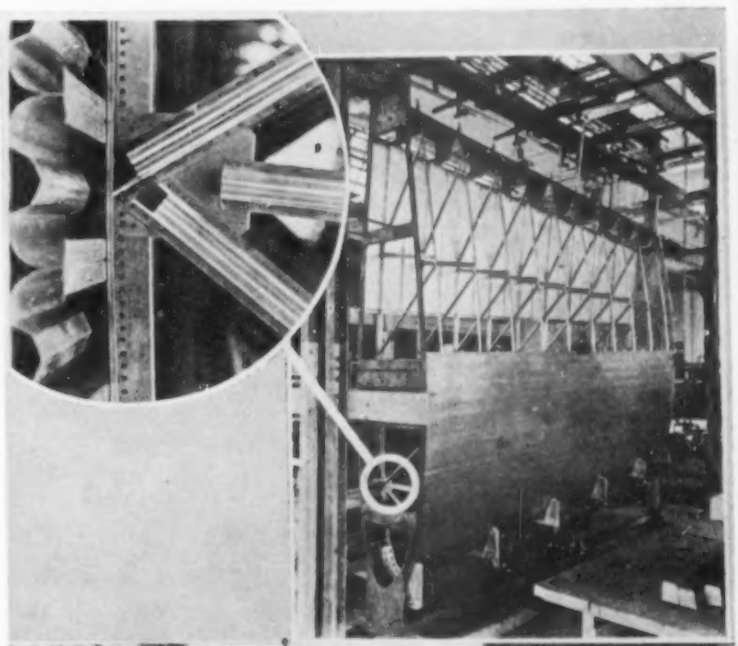
IT is possible to guarantee spot-weld strength in all types of metals with proper control and supervision; the degree of refinement should depend on the type of welded structure and its use. A method of control and supervision used in spot-welding highly stressed stainless steel structures is here described with the view of showing how a similar method could be applied to other materials. The growing use of resistance welding in highly stressed structures, the demand to reduce weight and the desirability to cut costs by eliminating "extra" welds, has brought about a need for guaranteeing spot-weld strength. This can be done with proper control and supervision of the main elements which make up a spot-weld: *Time, Current, Pressure, Electrode size and shape, Weldability* and with some metals, *Surface preparation.*

The Need for Spot-Welding Control and Supervision

Why is it that the days of the "foot-welder" with its haphazard control of time, current and pressure are numbered? Chiefly for three reasons: First, the increasing application of spot-welding to critical or highly stressed structures requires that every weld assume a predetermined percentage of the load. Second, the constant demand to reduce costs simply makes it uneconomical to put in any more welds than necessary. Third, competition forces industry to improve their products and to do so, appearance and uniformity of spot-welding are essential.

The purpose of this paper is to describe a method of control and supervision used in the Shotweld system to obtain guaranteed weld strengths in stainless steel structures and show that similar methods could be applied to assure weld strengths in other materials. For example, at the present stage of automotive design, there is probably a considerable excess of weld strength simply because manufacturers are not able to guarantee the strength of every weld. As methods of control and supervision improve, it will be possible greatly to reduce this excess with obvious savings in weight and cost. In the case of stainless steel structures, such as railcars, airplane wings and trailer bodies, it has been necessary to reduce the size of members, gussets and flanges in order to complete with other materials on a strength–weight ratio basis. The critical nature of these structures has spurred the development of a welding technique to assure their strength.

Fig. 1—Stainless Steel Wing Structure with Detail of Rib Stiffeners Welded to Gusset



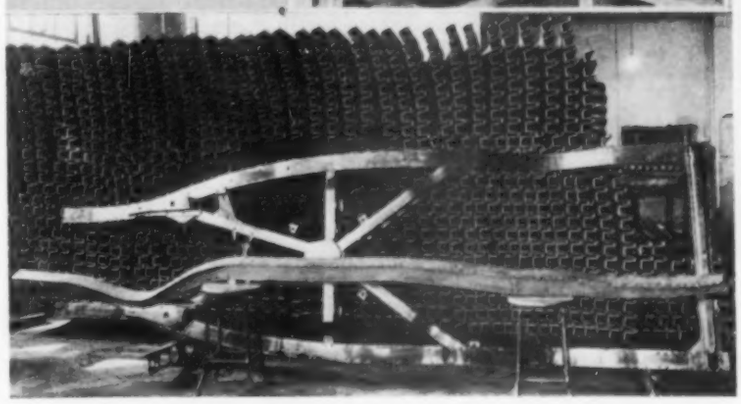
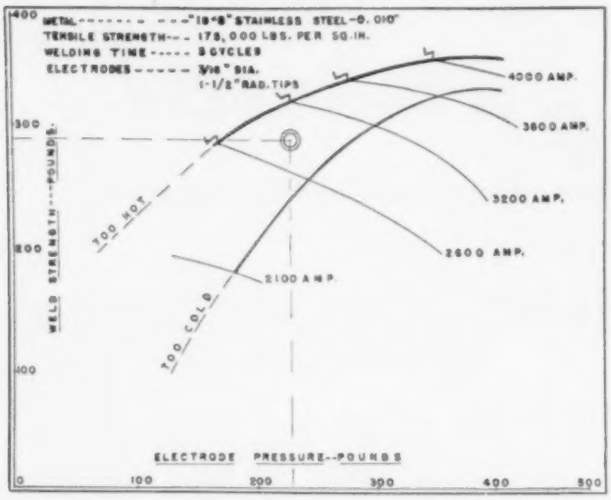


Fig. 2—Assembled Chassis Frame and Spot-Welded Longitudinal Member

* To be presented at the Annual Meeting, A. W. S., Philadelphia, Pa., Oct. 20 to 24, 1941.

† E. G. Budd Mfg. Co., Philadelphia, Pa.

Fig. 3—Graph Showing How Optimum Welding Conditions Are Selected



SHOP STAINLESS STEEL WELDING CHART

THICKNESS IN.	ELECTRODE DIAM. IN.	NET ELECTRODE PRESSURE LBS.	TIME (CYCLES)	MINIMUM WELD STRENGTH LBS. D. S. 1/4 H.	MINIMUM WELD STRENGTH LBS. 1/2 H F. H.	APPROX. WELD DIAM IN.	MIN. WELD SPACING IN.	MIN. LAP IN.	MIN. FLANGE WIDTH IN.
.006									
.008									
.010	3/16	230	3	230	275	.070	3/16	5/16	1/4
.014									
.020									
.030									
.050									
.060									
.080									
.100									
.125									

1. THE SAME ELECTRODE PRESSURE MUST BE USED AS WAS USED IN MAKING TEST WELDS
2. APPROVED WELD MUST HAVE PENETRATION IN OUTSIDE SHEETS BETWEEN 50 & 90%

Fig. 4—Form of Welding Chart Used in the Shop

Typical Examples of Guaranteed Strength Welding

An example of a highly stressed joint is the gusset connection of the stainless steel wing structure shown in Fig. 1. Assume that the maximum load in the vertical stiffener (horizontal in photograph) is 1200 lb. For the thickness of gusset and stiffener (0.010 in. full hard) the strength per weld guaranteed the engineering department is 235 lb. The total number of welds required is, therefore, 1200÷235 or approximately 5. The gusset is then designed to accommodate that number plus a margin, in this case 6, so that failure would not occur in the joint.

This method of approach is practically non-existent in the automotive industry because, first, it is difficult to predetermine joint stresses and, second, the novelty of spot welding has not yet worn off with the result that there is still a prevalent notion that ten welds can be put in as cheaply as one. However, this opinion is changing as evidenced in the recent design and construction of automotive parts of a stressed structural nature. Typical of these parts is the spot-welded longitudinal chassis member illustrated in Fig. 2, in which every weld must be counted on to assume a proportion of the load.

Function of the Laboratory—The Welding Chart

In the example cited, how do we know that 235 lb. is the correct weld strength? The starting point is the laboratory whose job it is to specify and describe the weld we wish to guarantee. Through a painstaking process involving many thicknesses and variations in the four variables, *Time, Current, Pressure, Electrode size and shape*, values of weld strength are tabulated. In the case of cold-rolled stainless steel, the amount of harmful carbide precipitation and size of annealed zone determine the weld *Time* for any given thickness; for the case selected (0.010 in.) it is 3 cycles. For this *Time* a graph (Fig. 3) is made summarizing these data of weld strength *vs.* electrode pressure for various values of current. The line marked "Too Hot" indicates the boundary of excessive expulsion of weld metal, and that marked "Too Cold" the limit below which weld penetration is insufficient. The low pressure-current region is characterized by low weld strengths which because of their small size have questionable resistance to fatigue. In this zone, for a given per cent drop in current, occurs a much larger drop in weld strength.

Welds made in the high pressure-current region require heavy, cumbersome tools, large transformers and cables. The weld diameter is large and difficult to maintain because of the tendency for the tips to flatten. Finally, the zone between the "Hot" and "Cold" lines is so narrow that slight changes in pressure or current would cause a weld to fall outside.

A compromise between these extremes gives the optimum conditions and in the case of 0.010 in. the values selected are:

Time	3 cycles
Current	2800 amperes
Pressure	230 lb.
Electrode size and shape	$1^1/_2$-in. radius tip
Minimum weld strength (full hard)	275 lb.

These optimum values for key thicknesses are then plotted and from these results a Welding Chart is made up together with other pertinent information. Figure 4 shows the form of this chart with the data for 0.010 in. filled in. In order to give the shop some tolerance, the engineering departments base their design on values of weld strength 15% less than those indicated on the Shop Chart. In the case of 0.010 in. this value is 275 (1−0.15) = 235 lb. This is the Engineering or guaranteed value.

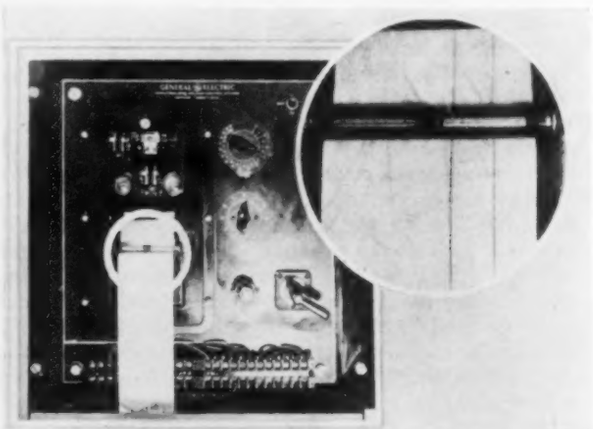


Fig. 5—Spot-Welding Control Panel Showing Ampere-Squared-Second Recorder, Time, Current and Recorder Controls with Detail of Recorder Tape Showing Weld Registrations and Limit Lines

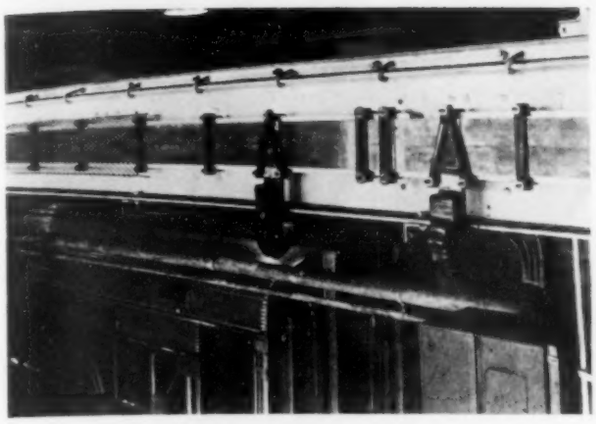


Fig. 6—Single-Phase Low Reactance Bus Feeder

Control of Time and Current

To help maintain the 15% weld strength tolerance, a weld recorder (Fig. 5) was developed whose function is to detect variations in *Time* and *Current* which would cause a drop in weld strength below that guaranteed. The energy delivered to the weld is roughly proportional to I^2RT, where I is the current, T the time of current flow and R the resistance of the weld zone. The recorder is a type of ballistic instrument whose deflection is proportional to I^2T. Hence a 15% change in either I^2 or T corresponds to approximately the same percentage change in weld strength. The recorder is adjusted so that the pointer deflection is halfway between the limit lines when the test weld is made. If the deflection should drop below the lower limit line (corresponding to a 15% decrease in I^2T) a bell rings and the timer is automatically locked out until reset. It is useful in detecting:

1. Variations in time—often caused by improper setting of time dial.
2. Poor voltage regulation.
3. Variation in current resulting from changes in secondary resistance or reactance, particularly in the case of portable welding tools.
4. Erratic tube operation.

The recorder is often used as an indicating instrument in cases where its setting is predetermined for various combinations of metal thicknesses. Its primary function is to "watch over" those elements of a spot-weld the operator cannot see, namely, *Time* and *Current*.

However the recorder is not by any means the complete solution of the control problem. In the case of alternating current welding, proper size and installation of transformers and feeders are of prime importance. For instance, suppose several welding machines, each with recorders, are connected to a distribution feeder having a 10% voltage drop when one machine is drawing current. Every time two or more machines "hit" together the drop will be 20% (corresponding to 36% drop in I^2) and the operator will have to "reset" his machine and reweld every time this occurs. If there are five machines all welding with 10 cycles, and each making 30 welds per minute, this drop will occur (for a minimum of $^1/_4$ overlap) approximately once every 4 welds per machine which is obviously too often.[1] The feeder would have to be designed in this case so that when three machines hit together (once every 33 welds per machine for a minimum of $^1/_4$ overlap) the voltage drop is limited to 8% (15% drop in I^2). The drop would then be excessive every time four come together, every 630 welds, or every 10 minutes, which would be reasonable.

Cable feeders of low reactance have been used successfully of which the most common are single phase of the interlaced or concentric type.[2] Illustrated in Fig. 6 is a single-phase bus type feeder of extremely efficient design which has been in successful operation for some time. The ratio of reactance to resistance is about 0.4, which is less than most concentric feeders, and much less than interlaced cable feeders. Total impedance is only 9% greater than resistance, with the result that voltage drop is practically limited to the resistance drop, and because it is out of phase with low power factor welding loads the actual numerical voltage drop is less than the resistance drop.

It is impossible in this paper to go thoroughly into the power supply question; suffice to say that it must be given studied attention before a reliable welding installation can be made.

The selection of supply voltage is of great importance. Where most of the equipment is of a portable nature requiring unprotected rubber-covered flexible conductors, the user may be forced, for safety, to use 240 volts. If this is not a consideration a higher voltage is desirable. For example, the per cent voltage (and I^2) drop of a 480-volt feeder is one-quarter that of the same feeder on a 240-volt system for equal power transmitted. The cost of feeders, switches and I^2R loss in the conductors is less for the higher voltage.

[1] The analysis of this problem in probability is too extended for inclusion here and will be made the subject of another paper.

[2] A very complete report by the A. I. E. E. Committee on Resistance Welding entitled, "Power Supply for Resistance Welding Machines," was published in The Welding Journal (Part I—May 1940, Part II—June 1940, Part III—June 1941). Complete data are tabulated for various types of feeders in Part III.

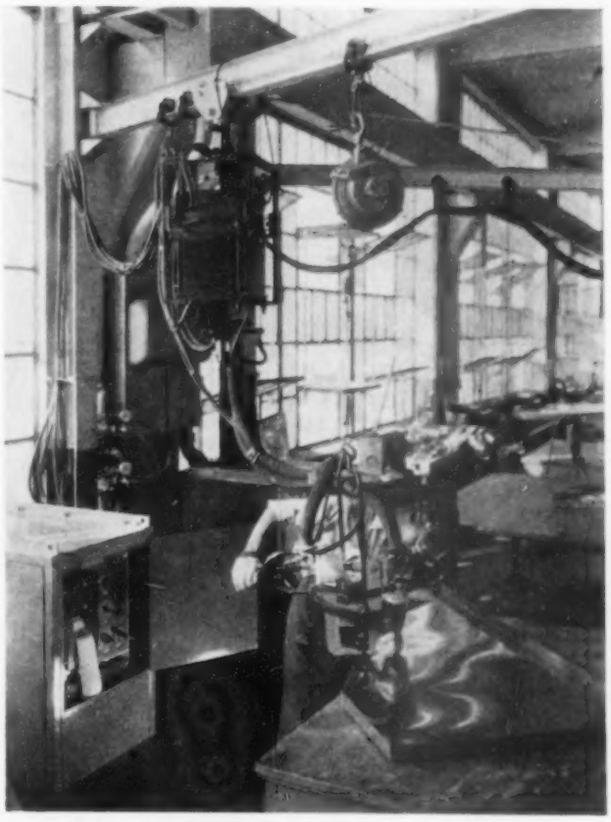


Fig. 7—Stainless Steel Welding Set-Up, Showing Portable Welding Tool, Transformer and Thyratron Control Panel

Table 1—A Classification of Spot-Welding Control Equipment

Suggested Classification	Type of Timer	Current Control	Other Equipment	Approx. Cost	General Characteristics
A Highly stressed structures	Synchronous (thyratron control type)	Ignitron tubes with vernier heat control in addition to welder transformer taps	Recorder or unusually close voltage regulation. Pressure timing with sequencing device for heavy welding	$2000 to $2800	±5% time variation; vernier current adjustment; pressure timing control; comparative record with test weld
B Moderately stressed structures with high inherent factor of safety	Synchronous (thyratron control type)	*Ibid.*	None	$750 to $1400	±5% time variation; vernier current adjustment; no pressure timing control other than pressure switch
C Lightly stressed structures where strength is of secondary consideration	Non-synchronous (mechanical pneumatic, etc.)	Synchronous contactor or ignitron contactor, with welder transformer taps	None	$200 to $800	±10% time variation; step current adjustment; inrush current transients; no pressure control

Type of Control

In order to make clear exactly what is meant by Type of Control, the commonly used equipment for spot-welding control is classified in Table 1. Class *A* control is the most highly refined and is therefore the most expensive. Variations in time are limited to plus or minus 5%; vernier current adjustment is provided by means of continuous heat control; the time of pressure application for heavy welding is controlled; and a comparative record of I^2T is made with the test weld. Cost $2000 to $2800.

Class *B* control omits the recorder and sequencing device for pressure timing control; its timing accuracy is plus or minus 5% and it provides vernier current adjustment. Cost $750 to $1400.

Class *C* is the least refined. Variations in time are a minimum of plus or minus 10% and current adjustment is by steps using transformer taps. Cost $200 to $800.

This somewhat arbitrary classification of control apparatus raises the controversial question as to whether or not there should be classifications of spot-welding. Although we all would like to guarantee the strength of every weld, it does not seem that this is possible when using either class *B* or *C* equipment. Is it not logical, therefore, to consider "grades" of spot-welding to correspond with classifications of control as, for example, welding of highly stressed structures (Class *A*); of moderately stressed structures where the inherent factor of safety is high (Class *B*); and of lightly stressed structures where strength is of secondary consideration (Class *C*)? The type of welding on stainless steel structures here discussed would be considered Class *A* spot-welding; the control and supervision to produce this grade of welding should therefore be of the same caliber. Figure 7 is an example of a set-up used for Class *A* spot-welding, showing welding tool, transformer, thyratron control and recorder.

Supervision

Without good supervision it is impossible even with the most elaborate equipment to produce guaranteed-strength welding. For any given set-up, three of the variables *Time*, *Pressure* and *Electrode size and shape* are specified in the Welding Chart. The fourth variable, *Current*, is determined with the aid of pull and etch tests illustrated in Fig. 8. For these tests a relatively simple type of testing machine (designed to take standard weld

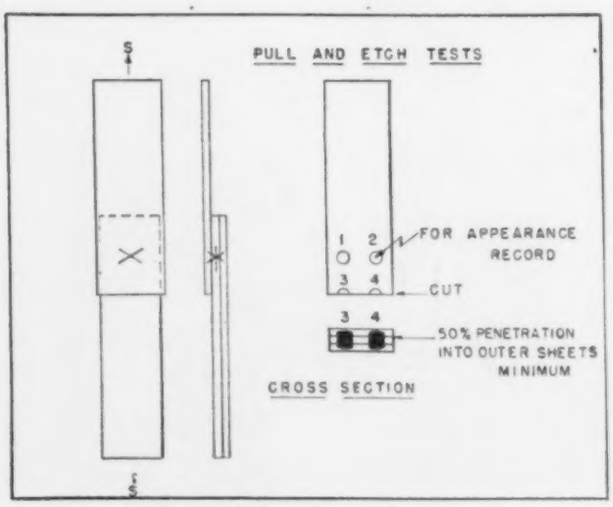


Fig. 8—Pull and Etch Test Specimens

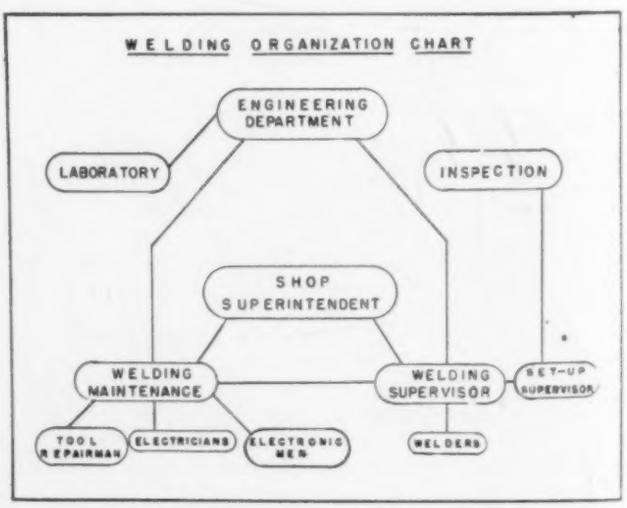


Fig. 9—Welding Organization Chart

STAINLESS STEEL WELDING RECORD

TEST WELD NO.	OPERATOR	JOB	WELD STRENGTH AND ETCH	TIMER SETTINGS AND TIP PRESSURE	TYPE WELDER	REMARKS
5	Smythe	Station 9 R.B stiffener to gusset	3 x 0.010" FH 295 E	CYCLES 3 CURRENT 40 PRESSURE 230	MACH. NO. 102 PEDESTAL D TOOL	
2				CYCLES CURRENT PRESSURE	MACH. NO. PEDESTAL TOOL	
3				CYCLES CURRENT PRESSURE	MACH. NO. PEDESTAL TOOL	

Fabler SET-UP SUPERVISOR.

Fig. 10—Form of Welding Record

test samples) and a suitable etching solution are all the equipment needed. The pull test assures strength; the etch test assures its consistency.

To insure an intelligent use of the welding chart, control equipment and weld tests, a clearly defined organization of the welding department is essential. I have made an attempt in Fig. 9 to construct what has been found to be a workable Welding Organization Chart. The lines connecting the various departments are contact lines as well as lines of authority.

The function of the Laboratory is to specify the material with respect to weldability and prescribe the procedure. The Engineering Department serves as the link between the Laboratory and Shop. The Welding Supervisor is responsible to the Shop Superintendent for production, but because of the technical nature of his job, he reports to the Engineering Department for the interpretation of welding procedures. He is responsible for *Strength, Appearance, Location* and *Number* of welds. In the usual shop organization welders report to job foremen. This set-up is not conducive to good welding because foremen are usually non-technical and over-concerned with quantity rather than quality. When necessary, welders are given a training course and are required to pass a qualification test.

The function of the Set-up Supervisor, who reports to the Welding Supervisor, is to make and record pull and etch tests. A form similar to that illustrated in Fig. 10 is used to record test weld strength, etch test, time settings and other data; this record is filed for reference. Before the welder is permitted to weld, the set-up is approved by the Set-up Supervisor. He makes check tests at intervals depending on the nature of the job.

The main function of the Inspection Department is to check appearance, location and number of welds. There is no satisfactory non-destructive test for spot-welds, and hence no true weld strength inspection. A proof load is usually impossible to make and, furthermore, does not test for all conditions of service. For this reason, Inspection checks the Set-up Supervisor to make sure he performs his job. If the welding set-up is correct, so will be the welds. There has been some question whether or not the Set-up Supervisor should report to Inspection. This is unsatisfactory because responsibility for weld strength is then transferred from the Welding Supervisor to the Inspection Department which is not in a position to assume it.

The Maintenance Department reports in a manner similar to the Welding Supervisor to Engineering and Shop Superintendent. Experience has shown that it is unsatisfactory to put Maintenance under the Welding Supervisor for two reasons. First, the Welding Supervisor is usually "non-electrical" and, second, he would never find fault with equipment set-ups made under his supervision.

How the System Operates

The example of the rib stiffener welded to the gusset may help to illustrate how the organization functions. We shall assume that the Maintenance Department has set up the proper tool and control equipment. First, the Welding Supervisor assigns a welder to the job. The latter checks the assembly drawing for thicknesses and weld pattern. He then dresses the electrodes with a special radius file and sets the tool pressure according to the Welding Chart. To do this he refers to a pressure calibration chart. He then obtains test samples of the same hardness and thickness as those in the pile-up to be welded. After making several trial welds, he then submits pull and etch tests, as indicated in Fig. 8, to the Set-up Supervisor. The latter checks and records them, then gives his "OK." The recorder was set before submitting the approved pull and etch tests so that 15% deviation in "*Current-squared* or *Time*" from the test weld will be detected.

If in the course of his work the recorder deflection should drop below the limit line, Fig. 5, he would then reweld. Should there be a succession of 3 "under-shot" welds he would readjust the heat control to bring the deflection back to normal. Under no circumstances is an operator allowed to adjust the recorder except in conjunction with a pull or etch test. Should the Set-up Supervisor request a check test at the end of the job, the test weld would then be made *before* the tips are redressed. All special conditions, such as unusual metal pile-ups, are referred to the Welding Supervisor. He must check all welding for he is responsible for weld strength.

Conclusion

This procedure is carried out to the letter on all aircraft welding. In the case of other stressed stainless steel structures, experience has revealed certain short cuts. For example, the etch test is omitted for thickness between 0.020 in. and 0.125 in. Outside of this range and on heavy pile-ups, where welding is more critical, it is used with the pull test. On production set-ups, time, current, pressure and recorder settings are posted for the combinations of thicknesses encountered so as to speed up machine adjustments. In this case the Set-up Supervisor makes periodic check tests.

This general scheme of spot-welding control and supervision could be applied successfully to critical structures of other materials. Experience has shown that the procedure outlined can be made to function smoothly and efficiently. Finally, it pays for itself in a very tangible way because it prevents expensive weld failures.

Uses of Flame Hardening in Machine Tool Production*

By A. L. Hartley†

MACHINE tool builders are confronted with the problem of producing parts to the close precision limits of the high production manufacturer. However, these close limits are specified on parts which are frequently manufactured in small quantities. In view of these conflicting factors, it is necessary to direct the research on a new process in such a manner that high precision results can be obtained from general data.

The machine tool builders recognized the advantages of the flame-hardening process several years ago. They could readily see where this method of hardening would permit them to heat treat many parts that had previously been impossible to harden. They also saw the possibility of using the process for hardening many parts at a reduced cost.

However, their engineers were reluctant to accept it because they could not find data on operating conditions that offered positive control and, therefore, were of the opinion that the process was not scientific and the quality of the work would depend entirely on the operator's skill. They also knew from past experience with carburized parts that hardening one side of a flat surface would set up internal strains and produce distortion. In view of these factors many companies who realized the process had merits were reluctant to adopt it; although some did adopt it on a very limited scale.

In considering the developments which led to the adoption of flame hardening as a standard operation in one machine tool plant we will divide this discussion into four sections.

In the first part a method of research will be briefly outlined, and the resultant curves for flame hardening both cast iron and steel by the Progressive Method will be considered.

In the second part the internal strains produced when flame hardening both cast iron and steel will be considered. In this section an analysis of the magnitude of these forces will be made and compared with those produced when parts are carburized and hardened.

In the third part a complete description of a universal flame-hardening machine on which most of the above work has been carried out will be given.

In the fourth and final section numerous typical applications will be mentioned. In this final section the use of special tips or burners will also be given consideration.

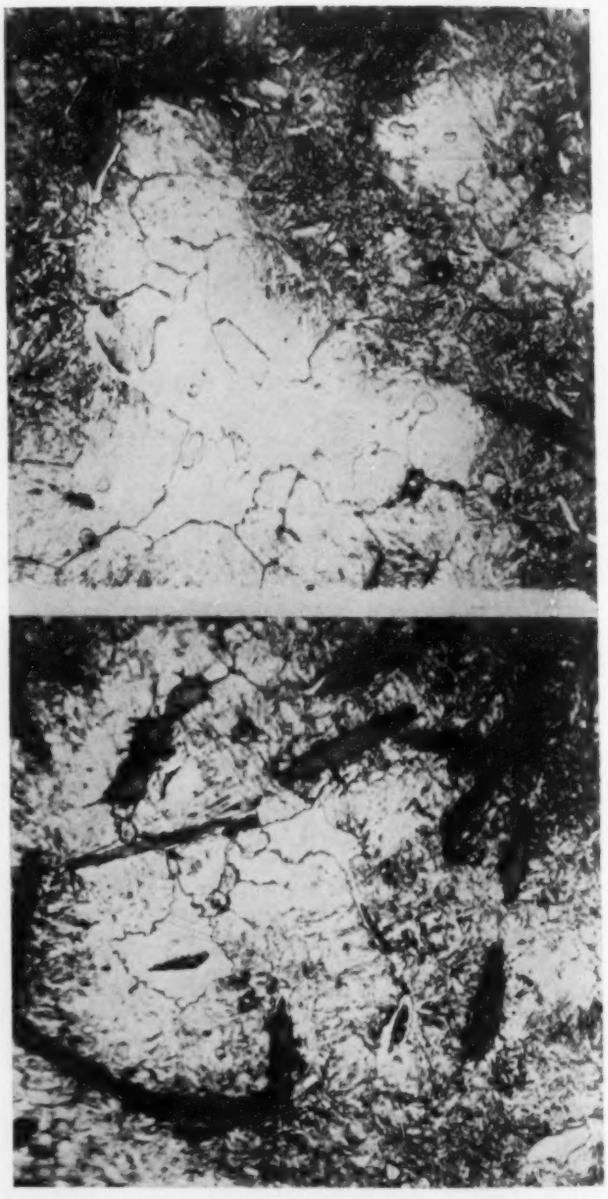


Fig. 1—These Photomicrographs Show the Inferior Microstructures Obtained When Cast Iron Is Flame Hardened Under Improper Conditions. 500 X Etched in 2% Nital

(Upper) Rate of travel 7⅜ in. per min. Tip or cone of flame 1/16 to 1/8 in. above surface. Other conditions adjusted to produce a 1/8-in. hard case.
(Lower) Rate of travel 4 in. per min. Tip or cone of flame 1/16 to 1/8 in. above work. Other conditions adjusted to produce 1/8-in. hard case.

Research Work

In the early stages of our flame-hardening experimental work all tests were confined to the Progressive Method of hardening flat cast-iron surfaces. It was realized that the nature of the work was such that it would be absolutely essential to standardize operating conditions and tabulate data in such a manner that experimental work on individual parts would be unnecessary. However, the first 150 or 200 tests seemed to in-

* To be presented at the Annual Meeting, A. W. S., Philadelphia, Pa., Oct. 20-24, 1941.
† Metallurgist, The R. K. LeBlond Machine Tool Co., Cincinnati, Ohio.

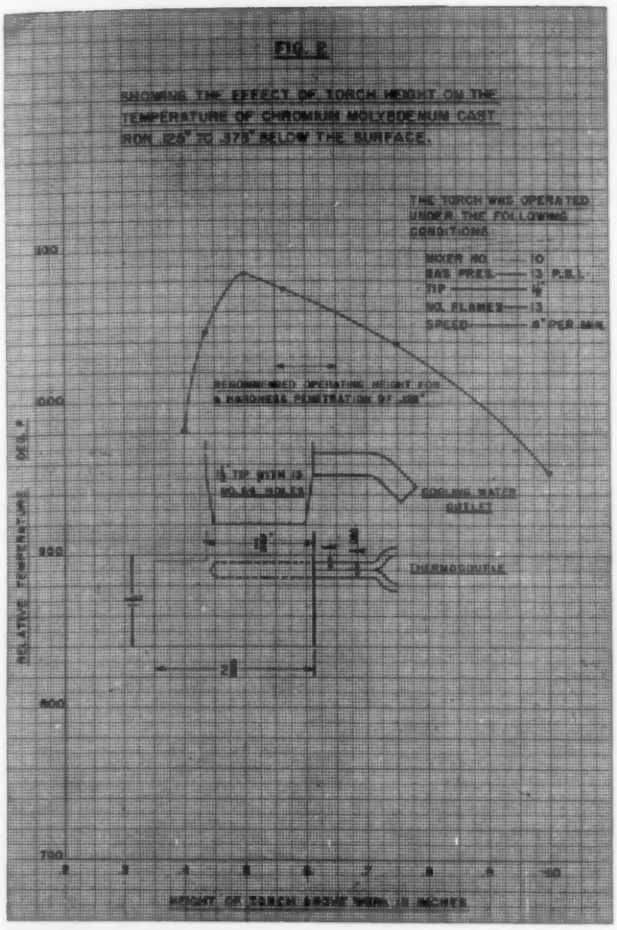


FIG. 2
SHOWING THE EFFECT OF TORCH HEIGHT ON THE TEMPERATURE OF CHROMIUM MOLYBDENUM CAST IRON .25" TO .375" BELOW THE SURFACE.
THE TORCH WAS OPERATED UNDER THE FOLLOWING CONDITIONS
MIXER NO. — 10
GAS PRES. — 13 P.S.I.
TIP — ½"
NO. FLAMES — 13
SPEED — 8" PER MIN.
RECOMMENDED OPERATING HEIGHT FOR A HARDNESS PENETRATION OF .035"
TIP WITH 13 NO. 64 HOLES
COOLING WATER OUTLET
THERMOCOUPLE
RELATIVE TEMPERATURE DEG. F
HEIGHT OF TORCH ABOVE WORK IN INCHES

Fig. 2—Showing the Effect of Torch Height on the Temperature of Chromium Molybdenum Cast Iron 0.125 to 0.375 In. Below the Surface

dicate that this would be practically impossible because it was found that the duplication of results was very poor. A careful analysis of these first tests indicated that the mistake had been in operating the tip or cone of the flame too close to the work surface. The microstructures showed definitely that the surface layer of metal had been overheated and was not suitable for machine tool parts. In the course of making these experiments the rate of lineal travel had been varied from $7^3/_8$ in. per minute to 4 in. per minute, but the microstructures as shown in Fig. 1 were typical results, and actual surface burning was a common occurrence. In addition to the poor surface structure shown, the transition zone between the hard surface and soft core was very abrupt.

Although there is no method of actually measuring the surface temperature of the material being hardened, it was felt that since flame hardening consisted only of rapidly heating the metal by conduction there was some method of accomplishing this in a manner which would produce uniform results and good microstructures. With this thought in mind a block of the dimensions shown in Fig. 2 was fabricated and a thermocouple was inserted as illustrated. The distance between the work surface and the tip of the torch was varied as shown, and the torch was repeatedly passed over the surface.

From this curve it can readily be noted that after the distance between the work surface and the tip of the burner was decreased to less than 0.5 in. ($^1/_2$ in.), the temperature at the thermocouples dropped off rather sharply. This more or less verified the idea that the tip of the burner had been operated too close to the work and surface melting had been taking place. This was concluded because in this series of tests the flames were not operated so close to the work surface that the burning action of the torch was in any way interfered with. The flames were not mushroomed into the work, and the outer cone was in all cases slightly above the work surface. It was, therefore, tentatively decided that the proper distance between the work surface and the tip of the burner should be between 0.55 and 0.65 in.

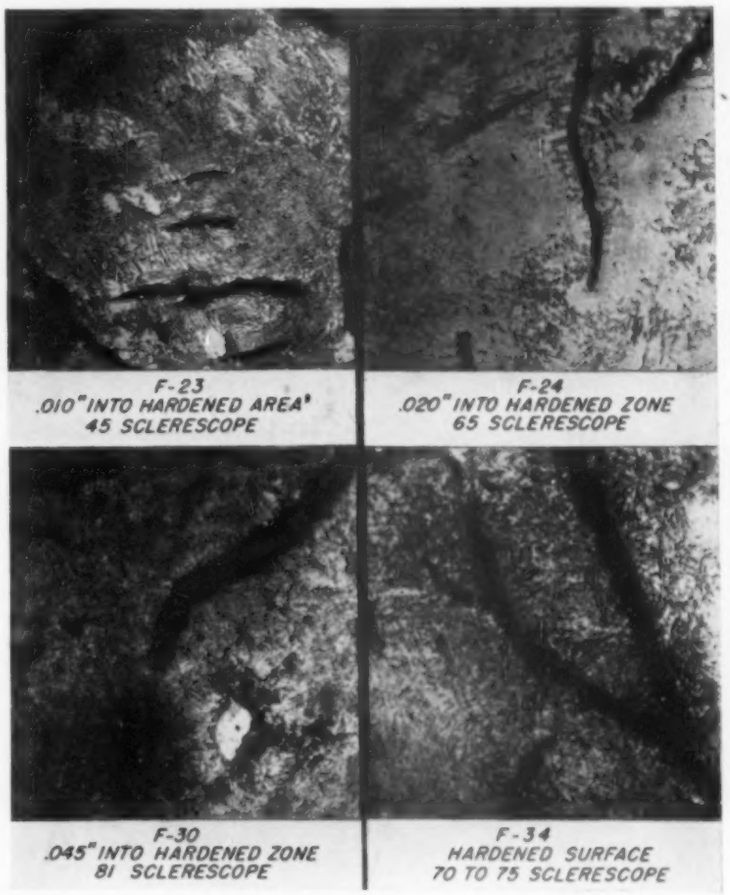


Fig. 4

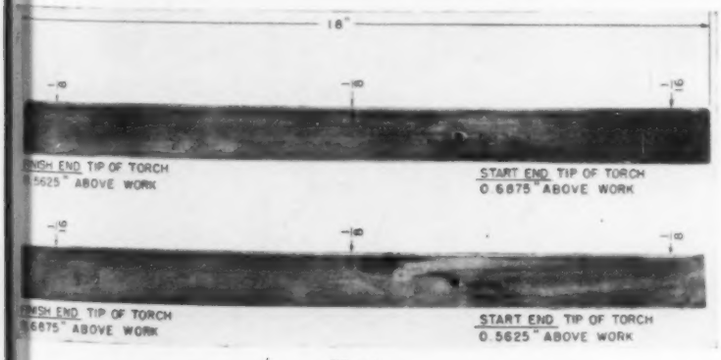

18"
FINISH END TIP OF TORCH 0.5625" ABOVE WORK
START END TIP OF TORCH 0.6875" ABOVE WORK
FINISH END TIP OF TORCH 0.6875" ABOVE WORK
START END TIP OF TORCH 0.5625" ABOVE WORK

Fig. 3

To verify this a test bar identical to the one shown in Fig. 2 was set up in the flame-hardening machine so that the distance between the tip of the burner and the work surface was $^{11}/_{16}$ in. at the starting end and $^9/_{16}$ in. at the finish end. The part was flame hardened under conditions which gave a satisfactory visual temperature. Without changing the operating conditions, a second piece which was identical in design was hardened but in

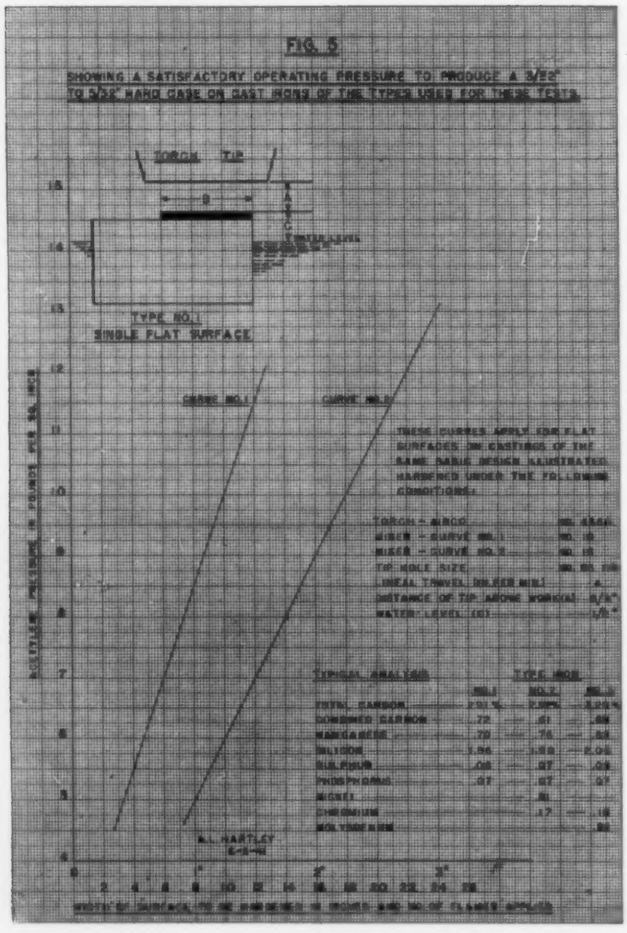


Fig. 5—Showing a Satisfactory Operating Pressure to Produce a 1/32 to 5/32 In. Hard Case on Cast Irons of the Types Used for These Tests

this case the distance between the work surface and the tip of the burner was 9/16 in. at the start and 11/16 in. at the finish. These bars were then sectioned and the illustration, Fig. 3, clearly shows the result; that is, the depth of penetration of hardness did not vary when the torch height varied from 5/8 to 9/16 in., and the direction of travel had no effect on the depth of penetration. A microscopic examination of these specimens showed a greatly improved microstructure and a broad transition zone.

The photomicrographs shown in Fig. 4 are typical of the gradual structural change which takes place when cast iron is flame hardened under proper operating conditions.

These preliminary tests seem to indicate that flame-hardening conditions might be standardized to such an extent that the process could be made suitable for machine tool work.

Accordingly an extensive series of tests was outlined and carried out. In the first place the structures produced when cast iron of the type which we were expecting to use, namely, chromium molybdenum alloy iron, was hardened by the furnace method were not generally known. Accordingly a complete series of small cubes was furnace hardened at 25° intervals from 1425° to 1700° F. These samples were then carefully polished and photomicrographs were made for reference use.

The next step was to standardize all of the variables in the flame-hardening set-up in such a manner that the microstructures produced by flame hardening would be identical to those produced by furnace hardening, because it was felt that when a flame-hardened and a furnace-hardened specimen of the same material had identical microstructures the temperature from which the furnace-hardened specimen was quenched could be considered the *effective temperature of the flame-hardened specimen*. By this it is not meant that the flame-hardened specimen was quenched from exactly the same temperature as the furnace-hardened specimen, but merely that the results are identical and, therefore, the effective temperature could be considered the same. To accomplish this duplication of results it was found after extensive experimental work that a torch operating height of 5/8 in. above the work with a rate of lineal travel of 4 in. per minute seemed to give the best uniformity in the particular case under consideration. However, it should not be implied that no other set of operating conditions could be satisfactorily used because those mentioned merely happen to be the ones on which the standardized data herewith considered are based.

The curves shown in Fig. 5 are representative of the results of this experimental work and illustrate a set of operating conditions which have proved very satisfactory for hardening single flat cast-iron surfaces. The curve illustrated on Fig. 6 shows a similar chart which was developed in the same general manner for hardening S.A.E. 4145 steel. It may be noted from this last curve that the operating height has been reduced for hardening the steel bar. This is because steel has a better rate of thermal conductivity than cast iron and permits the heat to be conducted into the material more rapidly.*

* The curves shown were based on the conditions in a given set-up and cannot be universally applied.

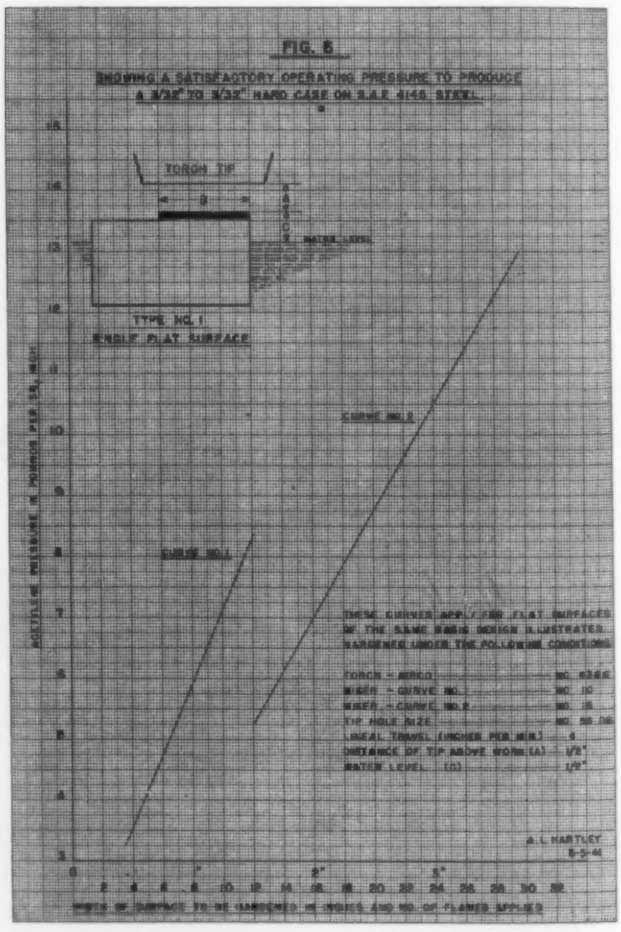


Fig. 6—Showing a Satisfactory Operating Pressure to Produce a 1/32 to 5/32 In. Hard Case on S.A.E 4145 Steel

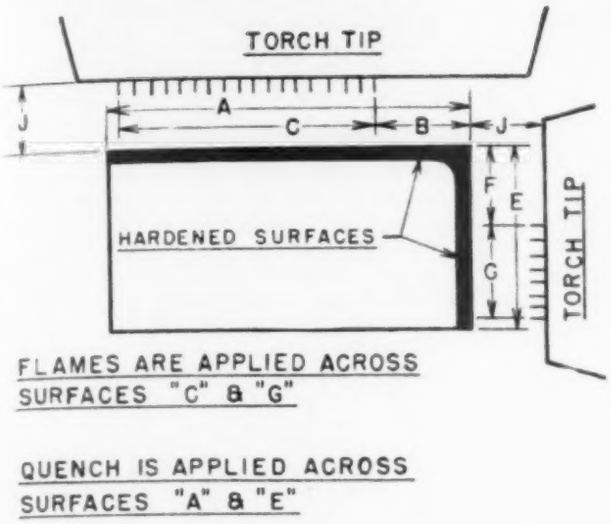


Fig. 7—Set-Up for Hardening Adjacent Flat Surfaces

Hardening Two or More Flat Surfaces Simultaneously

In hardening machine tool parts it is frequently necessary to harden two or more adjacent surfaces simultaneously. The procedure for hardening parts of this type can be standardized in the same general manner as that employed for hardening a single flat surface. However, in addition to standardizing the rate of lineal travel, gas pressure, etc., it is also necessary to establish standards for the dimensions *B* and *F* as shown in Fig. 7. A typical example of the results of flame-hardened parts from standardized data is shown in Fig. 8. This photo shows the uniform depth that can be obtained when a single flat surface is hardened and also when two adjacent surfaces are hardened.

The part shown in Fig. 9 is a typical example of a large casting which is flame hardened on three surfaces simultaneously. The surfaces *A*, *B* and *C* are hardened. The set-up for handling this part is shown in Fig. 10.

A brief discussion of the advantages of flame hardening a part of this nature will probably be of general interest. The particular part as shown is used to mount hardened steel cam plates for actuating the tools in a crankshaft turning lathe, and the only surfaces that have any wear are those on the head sections which must fit accurately in slides. The design of the machine in which these parts are used is such that it is absolutely essential that these surfaces do not wear, as that would permit backlash and cause tool breakage. Prior to the use of flame hardening it was necessary to make these parts from a heavy forging and heat treat them to the maximum hardness within the machining range, as the nature of the section would have made it very difficult to quench it to full hardness and finish by grinding. It would also have made it practically impossible to locate the cams accurately as it is necessary to drill and pin them in position after the part is completed and on the assembly floor. Although it might have been possible to produce this part by the carburizing method, the cost would have been almost prohibitive and the job would have been a very hazardous production problem. However, about two years ago the first of these parts were flame hardened and put in service. They have given excellent performance and at the same time resulted in a 40% reduction of cost. If the part had been of such a nature that maximum strength and toughness were required, it could have been made from a forging and flame hardened in the same manner as shown, and very appreciable savings would have been possible even if this procedure had been followed because of the fact that it would not have been necessary to machine the part in the hardened condition.

Distortion of Flame-Hardened Parts

Possibly the next most critical problem which the research engineer must face after flame hardening has

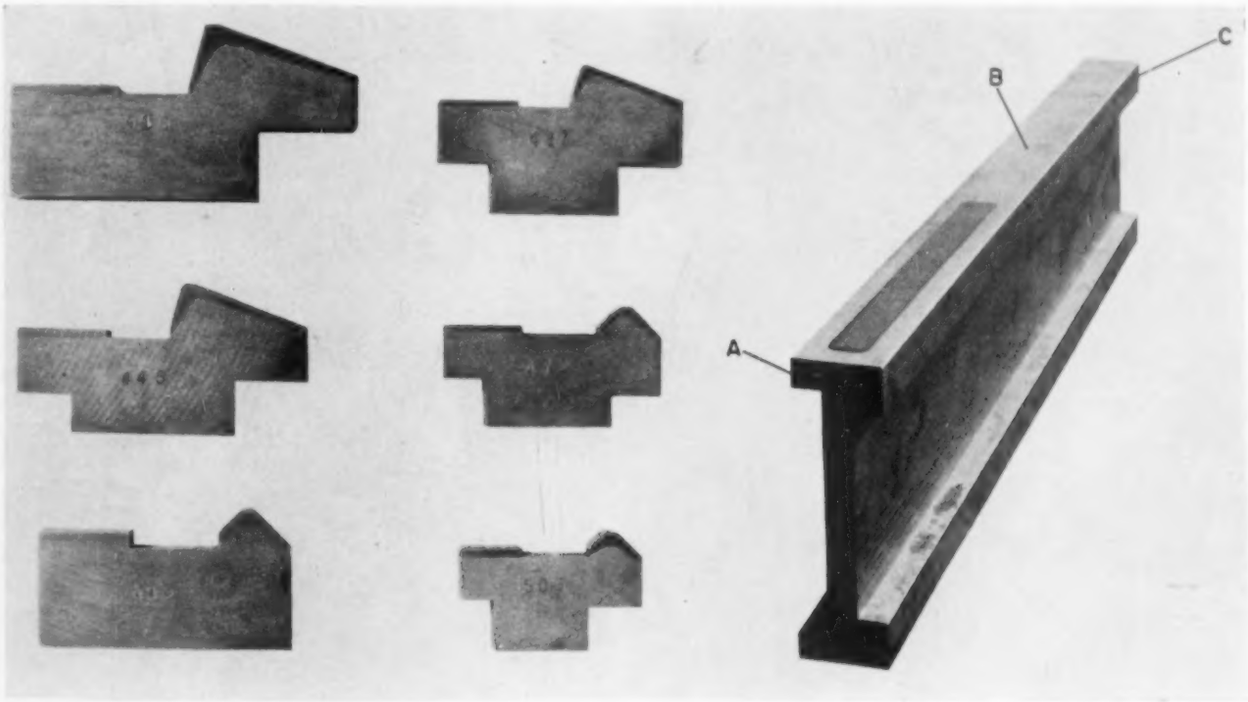


Fig. 8

Fig. 9

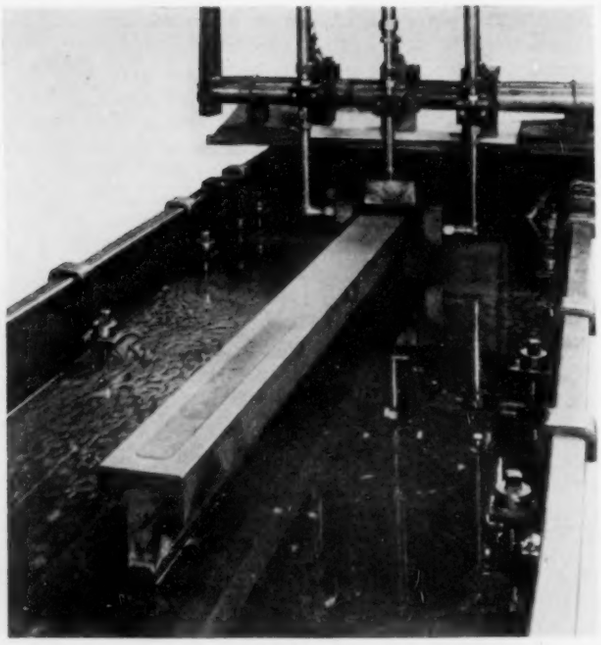


Fig. 10

been standardized to the point of obtaining uniform surface hardness with good microstructure is that of distortion and internal stresses. It is well known that machine tool builders must build their products in such a manner that the parts will stay in permanent alignment under severe operating conditions, and these conditions are becoming more and more severe as the use of sintered carbide and other improved non-ferrous cutting tools are being more generally applied. Therefore, the internal stresses must be carefully analyzed and corrected if flat surfaces used in machine tool construction are to be hardened by the flame-hardening process. The experiments on this subject have shown that the stresses between the hard and soft metal of a flame-hardened part are in the neighborhood of 30,000 lb. per sq. in. for S.A.E. 3140 or S.A.E. 4145 steel and 16,000 lb. per. sq. in. for chromium molybdenum cast iron. Although it has been found that these stresses can be reduced 40 to 50% by the stress relieving at 400° F., it was felt that they were too great to be permissible in machine tool parts. In the castings such as the one shown in Fig. 11 these stresses caused too much distortion to permit economic production, and it would not be advisable to use the parts even if they could be redesigned so that they would be heavy enough to prevent this distortion, because shock conditions to which the parts would be subjected in service would cause serious difficulty after the machines were in operation. Accordingly some method of strain balancing was absolutely essential if flame hardening was to be universally applied to this industry.

As previously stated only about 40 to 50% of the strain could be relieved by drawing the part at a temperature of 400° F., and further tests on parts of the nature shown in Fig. 11 proved that this stress relieving would not decrease the distortion but would actually increase it. For example, a part similar to the one shown was drawn at 400° F. for 2 hours and the distortion increased appreciably. It was then placed on a very heavy table and clamped in such a manner that the bow was in the opposite direction to the distortion caused by flame hardening, and redrawn at a temperature of 400° F. for a period of 12 hours. It was found that this treatment did not decrease the distortion of the part.

Although tests in which parts of this nature were clamped in a bowed position during the flame-hardening operation showed that they could be taken out of the machine practically straight, a short period in the draw

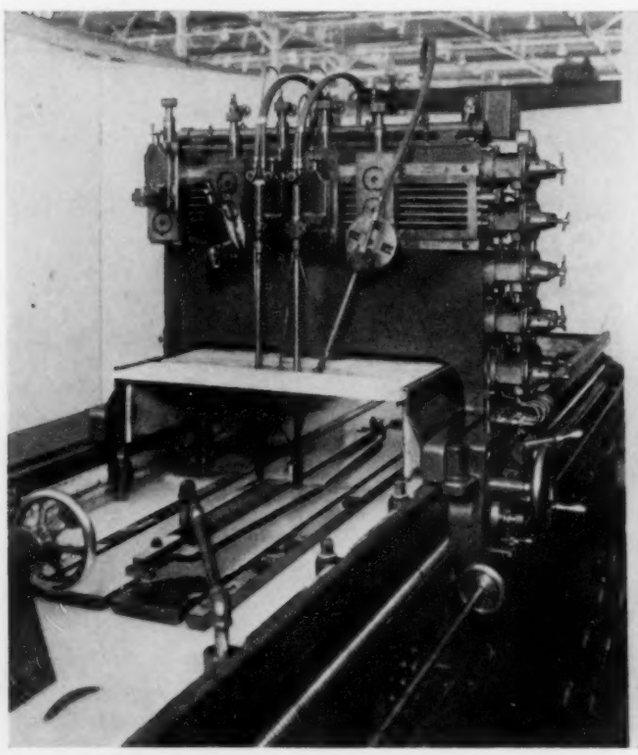


Fig. 11

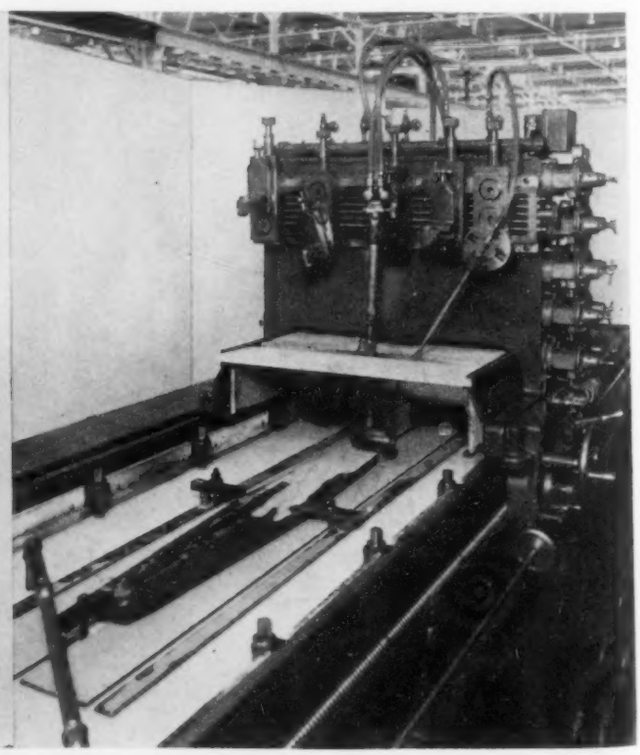


Fig. 12

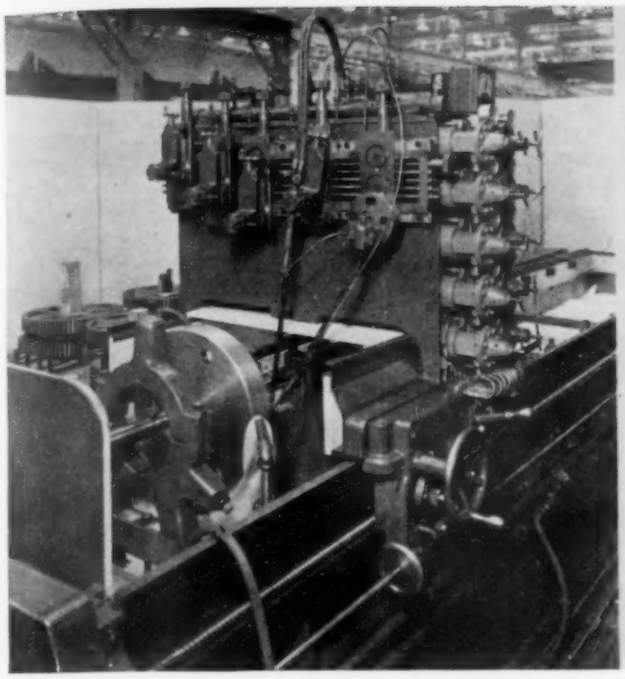


Fig. 14

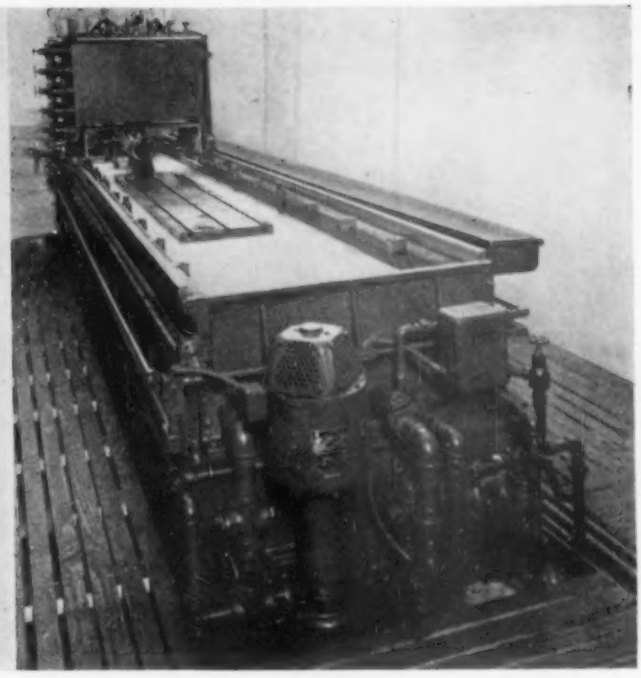


Fig. 15

furnace at a temperature of 375 to 400° F. caused them to take exactly the same shape as the parts which were not clamped in the bowed position. In view of these experiments it was decided definitely that pre-bowing or strain relieving under clamped conditions would not be acceptable for machine tool parts, and flame hardening of such parts would not be permitted if a better method could not be found for relieving the strains.

In view of the fact that the tests on both cast iron and steel have proved that the hardened layer expands when cut loose from the soft portion of the part, it was believed that the only possible manner of balancing these stresses was to turn the part over and flame harden it on the opposite side. This procedure was experimented with and found to work very satisfactorily. Parts such as the one shown in Fig. 11 are now hardened on a production basis, flame straightened and stress relieved by a 400° draw. They are usually delivered to the grinding department with the distortion not in excess of 0.004 in. The photograph shown in Fig. 12 illustrates the method of applying the flame-straightening operation. The amount of heat to be applied on the opposite side can only be determined by experimental work on the individual parts.

Although a question may be raised as to the detrimental effect of these balanced stresses on a part, it must be remembered that they are actually less than those in a carburized part which are approximately 59,500 lb. per sq. in. for a part which has not been drawn and 34,800 lb. per sq. in. for a part which has been drawn at 400° F. The reason for this greater stress can readily be seen if the mechanics of hardening a part by the two methods is analyzed. When a surface is flame hardened the core of the part is cool and only a small area under the flame-hardening tip is hot. When this area is heated it tends to expand, and the cold base metal which is stronger than the hot metal on the surface causes a slight amount of hot upsetting action. Then when the material is quenched and the martensitic structure is formed, an expansion takes place due to the volumetric increase which occurs when pearlite is transformed to martensite. Hence the net amount of strains is caused by the volumetric change of converting pearlite to martensite minus the change caused by the hot upsetting action.*

If the part is carburized, the entire section is heated and quenched. The outer case is the first part which is cooled. This tends to hot upset the core. Thus the core is actually slightly shorter after the hardening operation and the case is slightly longer due to the volumetric change caused by the transformation of pearlite to martensite. Therefore, the net amount of strain in this latter case is caused by the volumetric change due to the structural transformation plus the hot upsetting of the core.

Suitable Flame-Hardening Equipment

In the discussion up to this point only the fundamental principles involved in flame hardening have been considered. However, an attempt has been made to convey the idea that accuracy is of major importance. Now this accuracy cannot be obtained without the use of

* See Chapter 17, "Tool Steel Simplified," by Frank R. Palmer.

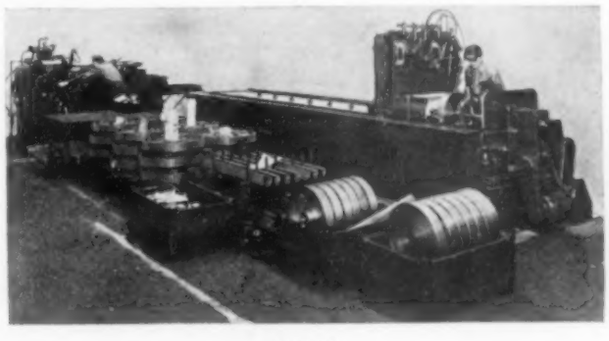


Fig. 13

Fig. 16

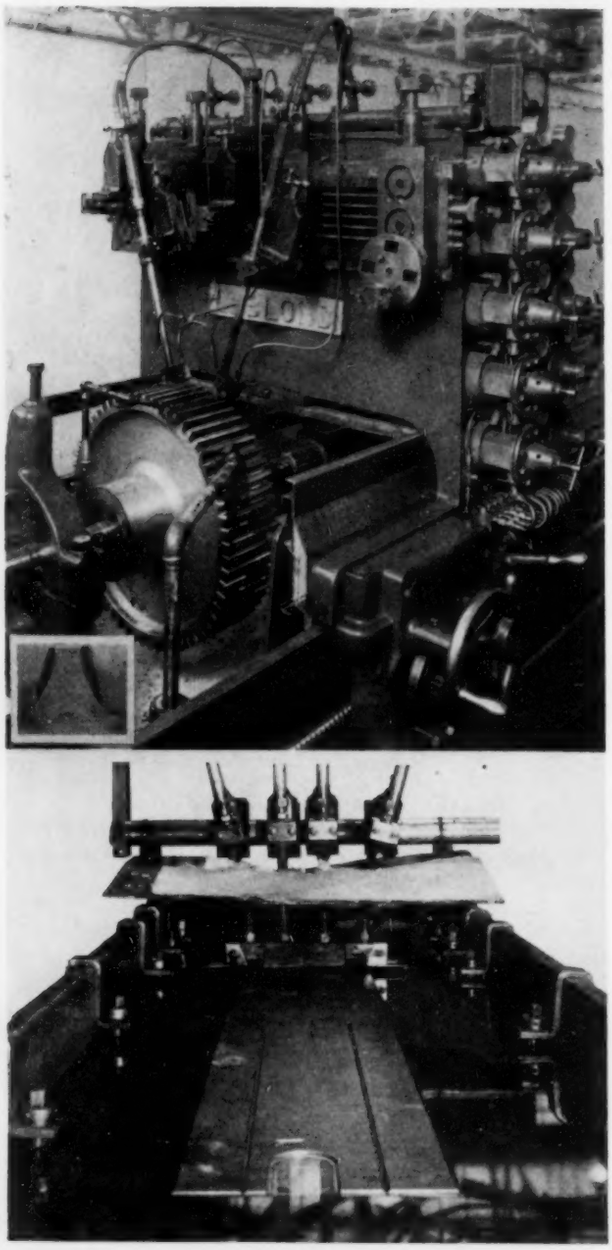


Fig. 17

proper equipment. That is, it is not meant to infer that the equipment must be expensive, but it must be designed to actuate the oxyacetylene equipment under conditions which can be accurately controlled. The machine shown in Fig. 13 is designed in such a manner that any desired rate of lineal travel of the carriage can be obtained. The carriage is actuated by means of a lead screw which drives into a train of gears in the apron. A tachometer mounted in plain view of the operator enables him to observe the rate of lineal travel of the carriage at all times and a handwheel conveniently located on the apron enables adjustment of any minor fluctuations in speed. Each torch has an individual oxygen and acetylene regulator which permits accurate adjustments of the gas flow. With these readily accessible controls it is possible for an operator to maintain constant operating conditions through any given cycle. In addition to these features the machine is equipped with automatic timing device so that any desired amount of dwell at the start of the hardening operation can be obtained and duplicated from part to part without the use of stop watch timing. It is equipped with an automatic trip dog so that the carriage can be stopped at any desired predetermined position. This feature is especially advantageous on gear hardening.

As may be observed from Fig. 14, the carriage is equipped to carry five hardening torches on individual cross rail heads. Each head is so arranged that the torches can be adjusted to any angle and also may be moved in and out for accurate alignment. The crosswise adjustment can be readily made from a position that is accessible to the operator without his being exposed to excessive heat. Figure 15 shows the tail end of the machine on which are mounted two circulating pumps. The pump on the left-hand side is a high volume circulating pump which keeps the water or cooling solution in the upper tank in circulation at all times so there is no possibility of it becoming excessively hot in the immediate vicinity of the work. The tank is so constructed that the cooling medium surrounding the work can be quickly drained into a lower sub-tank to facilitate more convenient loading of large parts.

In addition to the high volume pump used for circulating the coolant, the machine is equipped with a positive pressure gear pump which supplies the quenching medium to the torches, thus making it possible to accurately regulate the flow of water to each individual torch and thus provide a uniform accurately controlled quench. The circulating system is also so arranged that an automatic flush can be applied at the end of a pass to assist in hardening to a definite line. Although this talk is to be confined primarily to the discussion of flame hardening flat surfaces, the machine illustrated is equipped with a revolving spindle in the headstock so that long bars of any desired diameter can be hardened by the Progressive Spinning Method. The headstock will revolve at any speed from $^1/_{16}$ to 325 r.p.m. and of course this speed can be varied still further by changing the driving pulley on the headstock.

The sidewalls of the tank are protected from excessive heat by an insulating material, and the cooling solution. This prevents distortion which would affect the accuracy of the equipment.

Typical Applications of Flame Hardening in the Machine Tool Industry

The general view of a machine tool flame-hardening department is shown in Fig. 13. The parts surrounding this machine are typical of a few of the items which are normally being flame hardened on a production basis for machine tool equipment. Before the development of flame hardening it had been found practically impossible to harden the internal gears as shown in this illustration. The only method of heat treatment which had heretofore been practical was to heat treat the gears within the machining range and finish cut the teeth after this operation. However, with the flame-hardening method these parts are being successfully hardened on a production basis and are found to have very little run out. In hardening this gear a special design tip is used and the teeth are hardened individually by the Progressive Method.

Taper attachment bars are made from chromium molybdenum cast iron and are regularly hardened on a production basis. Bars of this type are hardened two

at a time, and the distortion is negligible because the opposite surfaces are hardened simultaneously and thus balanced stresses are produced which prevent any appreciable amount of distortion. The taper attachment shoe which rides on these bars is also hardened by the flame-hardening method and although not clearly visible can be observed in the box sitting adjacent to the bars.

Figure 16 shows a close-up view of a set-up for hardening large gears. In hardening these gears special tips were made so that accurate reproduction of results could readily be obtained. The inset on this photograph shows a tooth cut from one of these gears. It may be noted that a very uniform penetration of hardness is obtained. Two gears are hardened simultaneously, and two torches are used. This type of set-up greatly decreases the time which would be required if the gears were hardened one at a time with a single torch. In hardening parts of this nature they are indexed approximately 90° so that the heat distribution throughout the gear is uniform, and the resultant distortion is negligible.

To insure full hardness on the clash end of these gears a flush quench is applied to the end of the teeth just after the flames are extinguished. The construction of the machine is so arranged that this quench is applied automatically by a solenoid valve.

Another group of parts which are regularly flame hardened on a production basis is shown in Fig. 18. These are large cast-steel tool bars of S.A.E. 4145 analysis. They are approximately 5 ft. long and vary in width from 12 to 16 in. They are hardened on all four sides and the set-up shown in Fig. 17 is used. In hardening a part of this nature the bar is submerged in water until the surface only projects above the water level approximately $^1/_{16}$ in. In this manner the hardness of the corners tapers out into a $^1/_8$ x 45° chamfer. By using this procedure double corner hardening is avoided and at the same time soft streaks or strips along the edge are eliminated. Bars of this type are hardened with an average distortion of 0.005 to 0.010 in. Although the time limitation involved in this talk does not permit the showing of numerous photomicrographs, it might be of interest to mention that the transition zone between the hardened and soft area extends approximately 0.030 in., and the microstructure of the flame-hardened surface is equally as good as that obtained in a normal furnace-hardening operation.

Special Torches Used in Machine Tool Flame Hardening

The photograph, Fig. 19, shows a group of special torches which can be used in flame hardening machine tool parts. The first tip, *A*, is merely a thin tip designed to produce a short stubby flame so that the parts such as keyways, etc., in which space limitations control may be hardened. The tip *B* is a special gear-hardening tip, the application of which was illustrated in a

Fig. 18

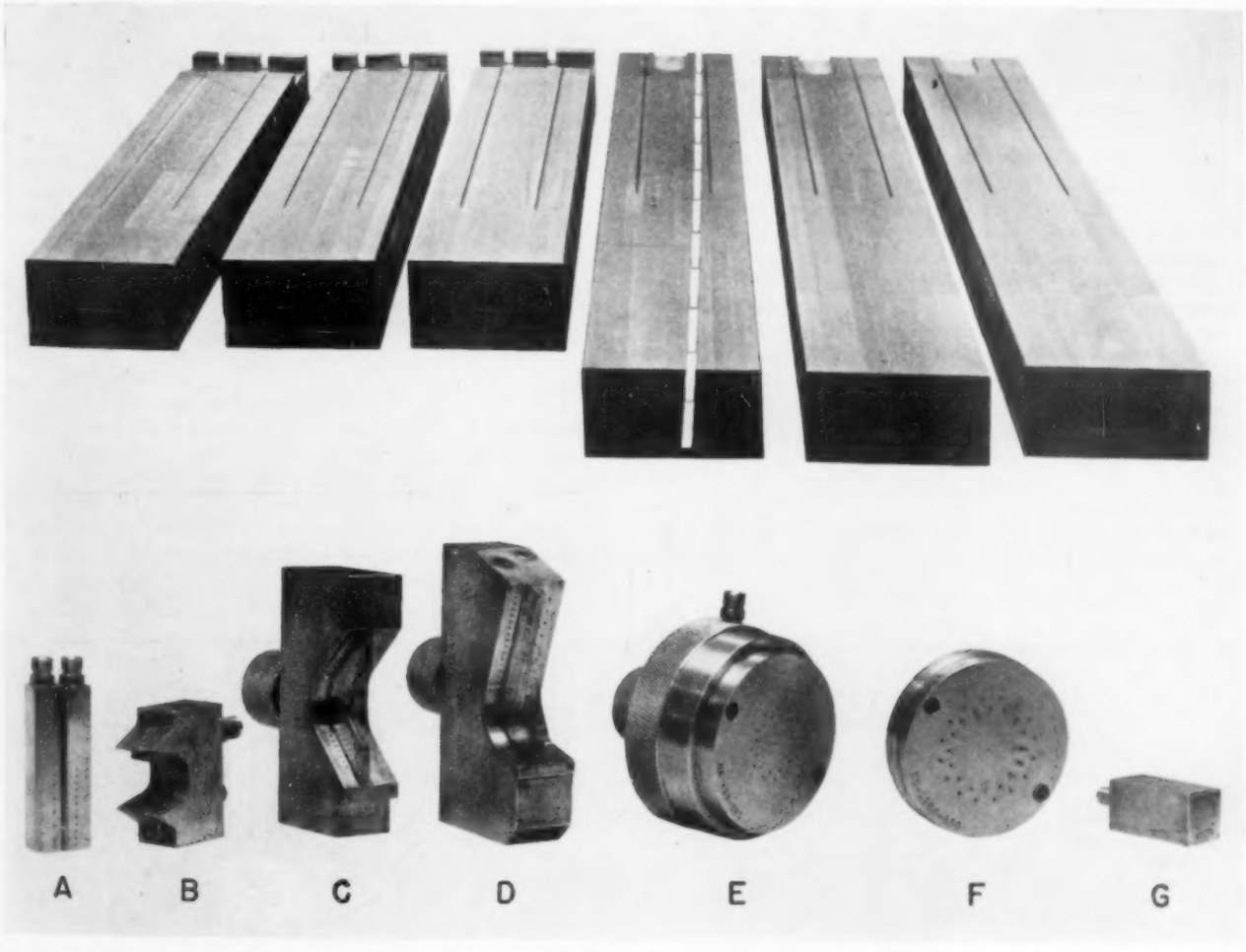


Fig. 19

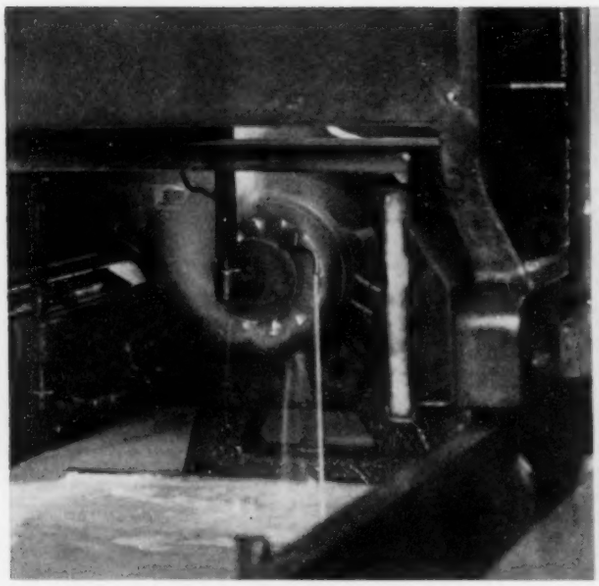


Fig. 20

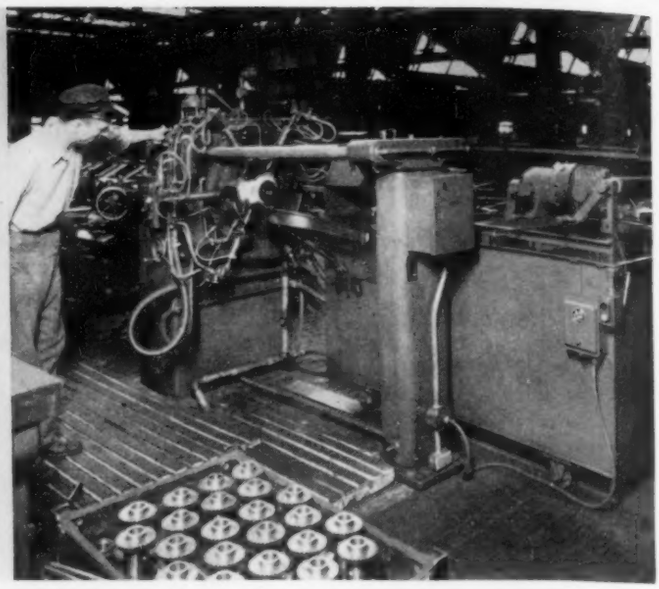


Fig. 21

previous photo. The tips *C* and *D* are of special design for hardening surfaces at right angles to each other and are designed with a water cooled fin to prevent the quench from interfering with the flame. The tip *G* is a small unit used for spot hardening and is not water cooled. It is suitable for work which requires only a cycle of a few seconds and a small amount of heat. The tip shown in *E* is a special cylindrical tip which is water cooled and *F* is an extra plate for same. A typical application of this tip is shown in Fig. 20. In this operation an internal flange in a spindle nose draw collar is flame hardened to a Rockwell hardness of 55 to 60.

Although numerous other tips have been designed in the course of machine tool flame-hardening work, these are representative of the types which can be applied and designs that can be readily made in any machine tool or first-class jobbing shop.

Although the foregoing discussion has been confined almost entirely to Progressive Hardening, extensive production work on hardening of gears by the spinning method is being done and these operating conditions are standardized. Figure 21 shows a typical set-up for hardening small gears. Very excellent uniform results are consistently obtained. The main advantage of flame hardening gears by the spinning method is to decrease distortion and eliminate scale. It has been found that gears of uniform sections can be flame hardened without producing any measurable amount of run-out which is a factor of major importance for machine tool builders.

Summary and Conclusion

The purpose of this paper was to outline briefly some of the developments and production work now in progress. It is our opinion that this process of heat treatment is only in its infancy, and a great deal more research is imperative if it is to reach the scientific stage to which it is entitled.

We feel that this research work must be carried out by the machine tool builders and the manufacturers of oxyacetylene equipment working in close collaboration. When this work has progressed to a more scientific stage, flame hardening will be used in many fields which have heretofore not given it consideration. This will open up a new market for both the machine tool builder and the manufacturer of oxyacetylene equipment.

Acknowledgments

The writer wishes to express his appreciation to the *Iron Age* for their courtesy in allowing him to draw freely from the article, "Flame Hardening Standardization" which appeared in that magazine as a series of articles from October 17 to November 14, 1940. He also wishes to acknowledge the splendid cooperation of The R. K. LeBlond Machine Tool Company and his coworkers in that organization.

Welding Metallurgy

By O. H. HENRY and G. E. CLAUSSEN

A series of lectures prepared for presentation in a fundamental course of metallurgy and metallography at Polytechnic Institute of Brooklyn under the joint auspices of the Institute and the New York Section of the AMERICAN WELDING SOCIETY. The lectures are reproduced in attractive booklet form, copiously illustrated—357 pages—with imitation black leather covers. Volume I consist of the first series of 10 lectures given by the New York Section in cooperation with the Polytechnic Institute of Brooklyn last year. Volume 2 includes the series of lectures given this past year. The price of the book containing both volumes is $1.50 per copy. Special prices can be arranged for quantity lots of 50 or more.

Structural Spot Welding—Consistency Control Methods*

By A. M. Unger†

SPOT welding is an old and well-known process which, under certain conditions, has proved to be an economical method for joining metals. At the outset, spot welding was used to replace screws, bolts and rivets for the attachment of various parts, but only where no great strength was required. In the past decade, the use of spot welding has been extended to include the joining of highly stressed structural members. Such use has required a change in the technique of spot welding and the development of improved spot welding equipment.

The introduction of materials for structural purposes, other than ordinary steel, has also required considerable study. At present in the railway car-building industry four materials are used for structural purposes—mild steel (A. S. T. M. Spec. A113-39; A. A. R. Spec. M-116-37), 18–8 stainless steel, low-alloy high-tensile steels and aluminum. So far, spot welding has not been used for joining aluminum structural members in railway car construction. The spot welding of aluminum for structural purposes is now under extensive investigation by the Resistance Welding Research Committee of the AMERICAN WELDING SOCIETY and the subject of this paper is therefore restricted to the spot welding of the other three—namely, mild steel, 18–8 stainless steel and the low-alloy high-tensile steels, all of which have been employed in the railway car-building industry in spot welded structures.

* To be presented at the Annual Meeting, A. W. S., Philadelphia, Pa., Oct. 20 to 24, 1941.

† Welding Engineer, Pullman-Standard Car Mfg. Co., Chicago, Ill.

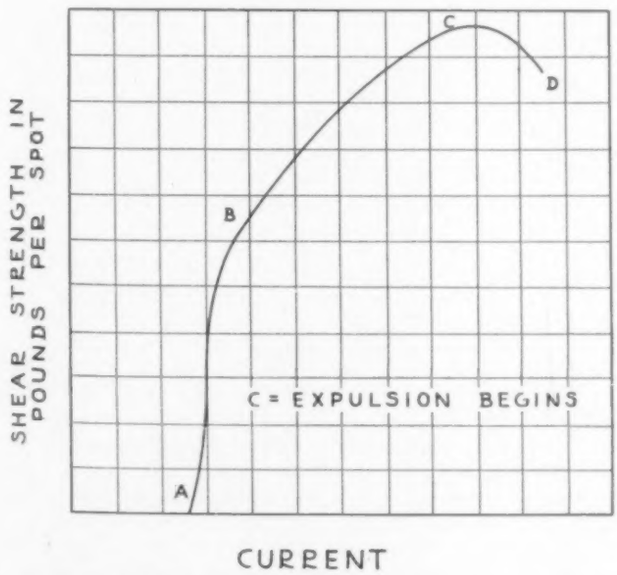


Fig. 1—Typical Shear Curve for Spot Welds, Illustrating the Effect of Current Variations on Material Over 1/16 Inch in Thickness

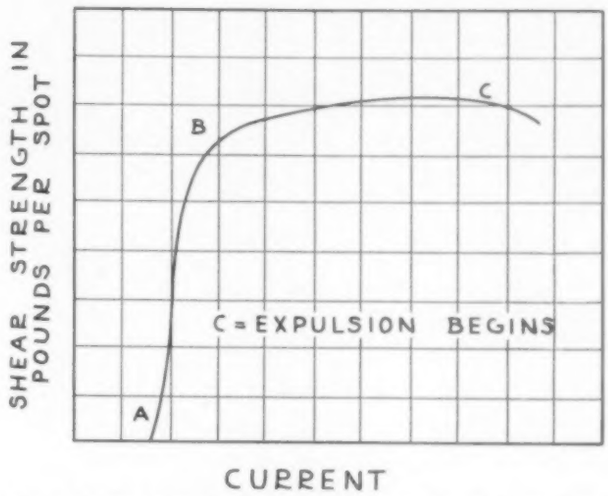


Fig. 2—Typical Shear Curve for Spot Welds in Material Less than 1/16 Inch in Thickness

Consistency of Spot Welds

In considering the strength consistency of spot welds, it is necessary to review the spot welding characteristics of each of the materials, as well as the factors in the welding operation which influence uniformity in strength of the spot welds. Primarily because of the difference in electrical conductivity of the three materials, the amount of current and the duration of current required will vary. The optimum spot weld in 18–8 material is made in 4 cycles in the case of the very light gages, that is, those in the vicinity of 0.020 in. Such small gages are seldom used in the structures of railway cars. The average gage used in railway car structures would probably be 0.060 in., in which case 12 cycles is the prescribed current duration for spot welding stainless steel, while 20 cycles for low-alloy steels and 15 cycles for the ordinary steels are recommended.

The effect of current variation on the strength of a weld is shown in Fig. 1. This curve shows how the shearing strength of the weld varies as the current is increased from zero to the point where it begins to damage the steel. The curve begins at point A, which is the value of current that will produce enough heat to raise the contacting surface of the two sheets to a plastic temperature plus the heat loss by conduction and radiation. Portion AB of the curve has a very steep slope. The spot underneath the electrode reaches a welding temperature practically simultaneously over the entire area. This causes a sudden jump from no weld at all to a strong weld. Very erratic results are obtained with current values from A to B on the curve. Slight variations in electrical contact resistance between sheets and between electrodes and sheets will cause large variations in the results on this part of the curve. From B to C the

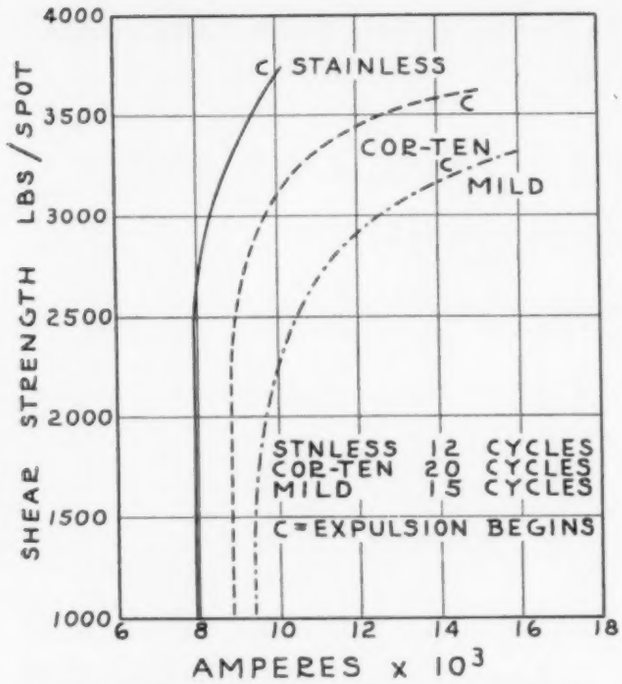


Fig. 3—Shear Strength Curve of Spot Welds in 16 Gage Steel

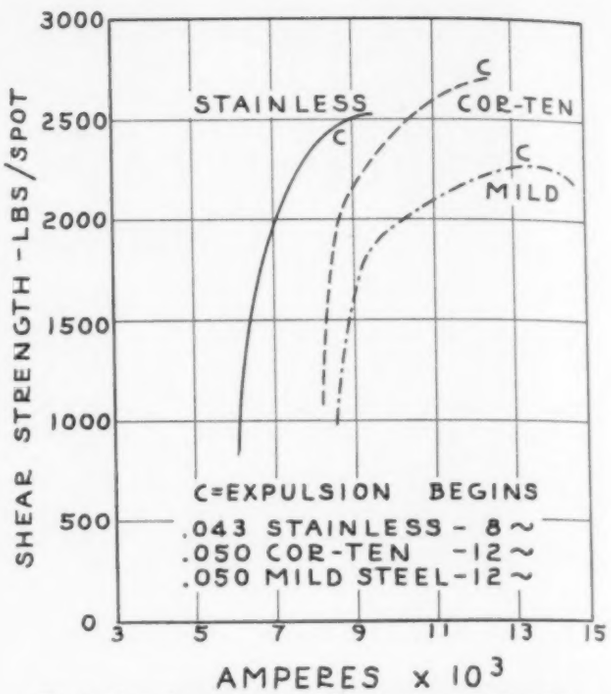


Fig. 4—Shear Strength of Spot Welds in 18 and 19 Gage Steel

strength increases. The spot is growing larger on the contact surface of the two sheets, exceeding the size of the electrode tip. The strength of the spot weld is proportional to the square of its diameter. When point *C* is reached, several factors act to decrease the strength. Shrink holes or cracks are produced, and the spot is weakened by deep indentation. The portion between *B* and *C* is the welding range. The machine should be set a little below *C*. This will give the highest strength spot and will allow the electrodes to mushroom some without decreasing the current density below point *B*.

Such a curve necessarily indicates only general characteristics, as its shape will vary with the kind of material welded and its thickness. The shear test of spot welds is influenced to a variable degree by the distortion of the test specimen in the vicinity of the spot weld due to eccentricity, the degree of stress concentration and the yield strength of the material. The influence of these variables is more pronounced when welding thin gage materials.

The curve shown in Fig. 1 represents typical conditions for sheet thicknesses of $^1/_{16}$ in. or more. For thinner sheets the curve takes a different shape as shown in Fig. 2, and it will be noted that in this case the strength of the spot weld does not increase materially with higher currents. In addition to the factors previously mentioned, in the heavier sheets the current has an opportunity to spread more because of the greater distance it travels through the sheet thereby heating a larger area. The pressure is also distributed over a larger area because of the increased stiffness of the heavier sheet, and therefore the spot can grow in size as the heat is increased by raising the current. In the thinner sheets the current and pressure are more concentrated because the sheet is more easily deformed and the weld does not grow appreciably in size as the current is increased.

The effect of current variation on spot welds of the three materials mentioned above can best be realized by a study of a Current-Shear Strength curve. Figures 3 and 4 illustrate Current-Shear Strength curves of spot welds in two commonly used gages of the three materials—mild steel, a low-alloy steel and 18–8 stainless steel. It will be noted that variation in current is much more critical in its effect on the strength of spot welds in stainless steel than it is in the low-alloy or the ordinary steel. Because of the low electrical and heat conductivity of stainless steel the heat generated is concentrated in the weld, whereas in the other two steels the heat flows out farther into the metal surrounding the weld.

While shear strength is the only quality of the spot weld that has been considered in this study of the effects of current variation, it should not be inferred that this is the only property of importance in the design of a spot welded structural joint. Probably of greater importance is the fatigue strength value of spot welds, but this quality is so influenced by the particular design under consideration, and the difficulties and the length of time required to make the test are so great, that it precludes the use of this quality in evaluating the effect of current variation. The shear strength of spot welds appears a satisfactory, as well as a practicable criterion for this purpose.

Factors Affecting Consistency

The heat developed in a spot weld is shown by the following formula:

$$H = I^2 Rt$$

where H = Heat
I = Current passing through the weld
R = Electrical resistance of the path of welding current in the piece being welded
t = Time or duration of welding current

To maintain consistently high quality welds it is necessary that the three factors, current, resistance and time, be kept constant. The time of current dwell (t) is held constant by using a good timer that will duplicate for each weld the same length of current application. Several good timers are now on the market.

Resistance of the weld (R) is affected by several factors such as electrode size, surface conditions and electrode pressure. Electrode size is kept constant by using machined electrode tips and changing frequently at proper intervals. Surface conditions are taken care of

by careful inspection, and electrode pressure is kept uniform by using pressure regulators.

The remaining factor, magnitude of welding current (I) is the most important, as the heat developed depends upon the square of its value.

The current is set by adjustment of the tap changer setting on the welder itself or it may be set by using the standard phase shift control on an electronic synchronous timer. This timer is capable of starting the current at any desired point in each half cycle. By delaying the starting, the effective value of the current is reduced. This is a very convenient method of current adjustment as it gives practically an infinite number of steps. After the current is set by whatever means used, whether the magnitude remains constant or not depends primarily upon the line voltage.

When the line voltage varies the operator of the spot welder cannot do anything to prevent it from affecting the quality of the weld he is making. If the supply line is well regulated and backed by an adequate power supply, the variations will be small. If the supply line is long and there are several welders or other equipment on the same line, the variations may be serious.

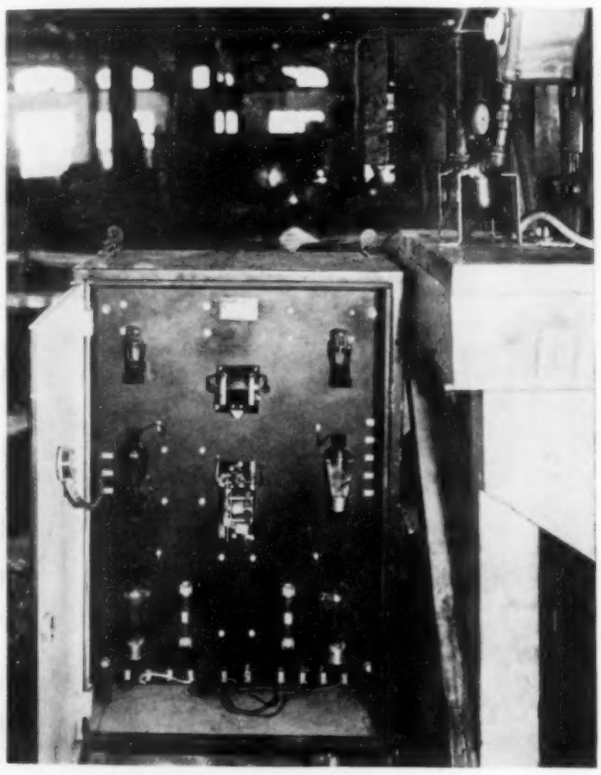


Fig. 5—Spot Welding Compensator

When and to what extent this condition occurs is not predictable, which precludes making adjustments to compensate for this voltage drop. It is generally agreed that because the time of current flow in spot welding is so short, the chances are high that not more than one of the welding machines on the line will be functioning at the same time. Nevertheless the possibility exists that the welding impulse of several machines may coincide and efforts to overcome this variable are therefore justified. This is particularly true when applied to the joining of materials of low electrical conductivity as illustrated on the Current-Shear Strength curves of Figs. 3 and 4.

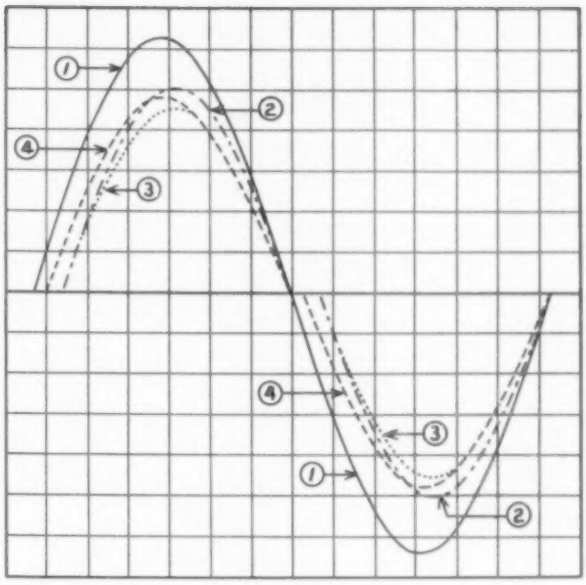

① FULL WAVE, NORMAL VOLTAGE
② PHASE SHIFT TO GIVE DESIRED WELDING HEAT, NORMAL VOLTAGE
③ CURRENT REDUCED BECAUSE OF VOLTAGE DROP
④ CURRENT SHIFTED IN PHASE BY COMPENSATOR TO GIVE SAME CURRENT VALUE AS ②

Fig. 6—Wave Form of Welding Current Showing Action of Compensator to Keep Current Constant

Consistency Controls

Various voltmeter, wattmeter and ammeter indicating arrangements have been used by manufacturers when spot welding, to signal current variations; but any device which merely indicates is insufficient, in that a poor weld has already been made before it is known. In the case of a voltage drop in the primary circuit, a signal that this has occurred is of little value, because no satis-

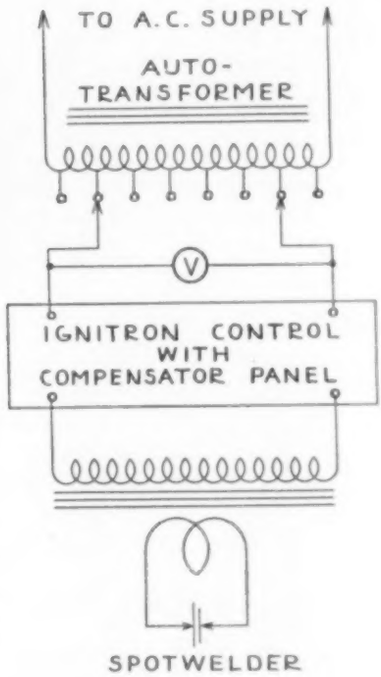


Fig. 7—Schematic Diagram of Connections Used to Test Compensator with Auto-Transformer

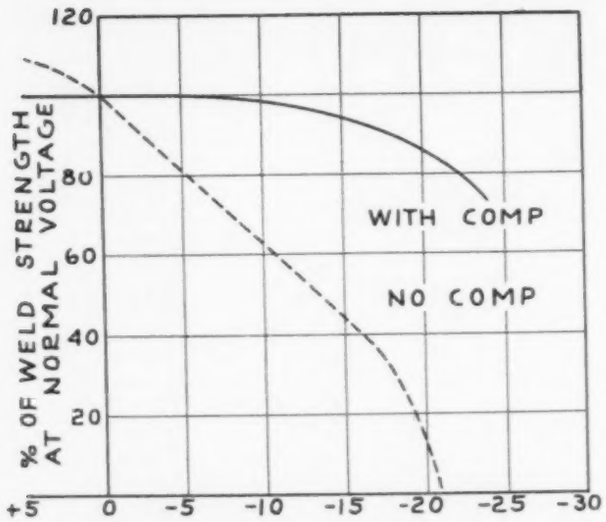


Fig. 8—Variation of Weld Strength with Line Voltage Test of G. E. Type CR7503-D117 Auxiliary Welding Panel. 16 Gage Stainless. 12 Cycles

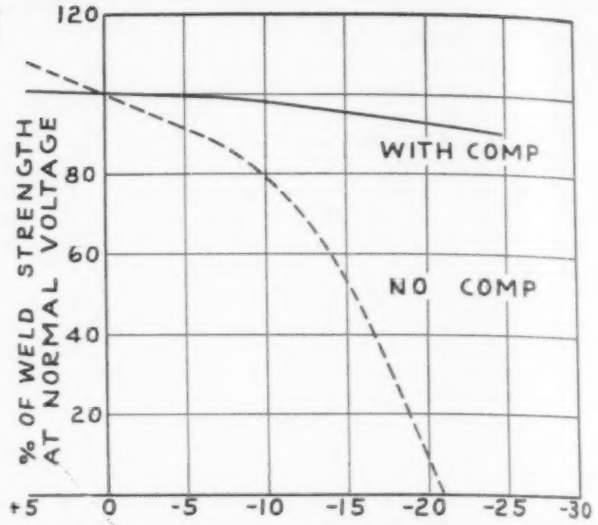


Fig. 9—Variation of Weld Strength with Line Voltage. 16 Gage Cor-Ten. 20 Cycles

factory adjustment can be made by increasing the weld setting to take care of this for future spot welds, as in the next welding operation the voltage may have returned to its normal value so that an overheated weld would be made. It has probably appeared to many that this important factor of current should be controlled or compensated in such a definite way that variation in primary voltage would not disturb the energy input to the weld.

It is interesting to note that a patent now expired, No. 1,230,357 issued to H. R. Woodrow on June 19, 1917, related to a very simple arrangement, apparently intended to perform this function. In his patent application, Woodrow disclosed "a certain new and useful Improvement in Devices for Controlling Energy Delivered to Welding Electrodes." This method utilized a watt-hour relay to automatically lengthen the duration of the weld (t), thereby compensating for any reduction in the magnitude of the welding current (I) and keeping the energy to the weld (I^2Rt), constant.

In our research effort several schemes are being studied, seeking methods to keep the energy input to the weld constant. In our pursuit of this development, we found a device which had been developed in the laboratories of one of the leading electrical manufacturers. The principle of this particular device was in line with what we were seeking, so arrangements were made for the manufacturing of such a panel which we have experimented with for several months. This device is not satisfied with merely indicating a variation in welding current due to a voltage drop in the line supplying the welder, but it automatically adjusts the current to keep it constant regardless of line voltage variations. We have chosen to call this device a Spot Welding Compensator (Fig. 5).

Spot Welding Compensator

The Spot Welding Compensator is a control device developed to keep the current being delivered to a spot weld constant regardless of line voltage variations. This compensation is brought about by automatically shifting the phase control of the welding current. If the line voltage drops, the Ignitron tubes are made to conduct current for a longer period of time during each half cycle, so that the effective value of the current is brought up to normal. If the line voltage rises, the tubes are made conductive for a smaller portion of each half cycle, bringing the effective value of the welding current down to normal.

The phase shift of the current to produce this compensating effect is illustrated in Fig. 6. Curve 1 is the wave form of the current when the phase shift is 100%. Curve 2 illustrates a reduced value of current where the starting point of the current flow has been delayed to give an

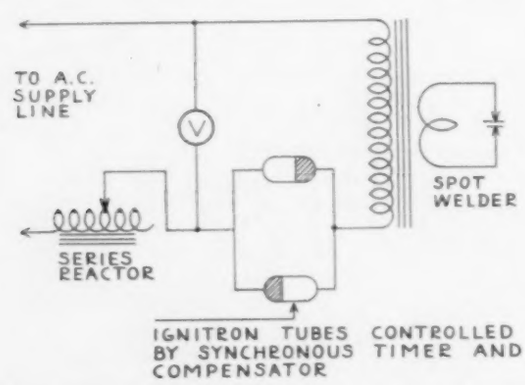


Fig. 10—Schematic Wiring Diagram of Set Up Used to Test Compensator

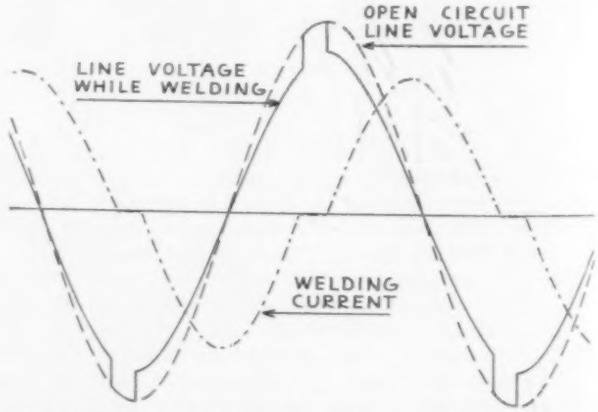


Fig. 11—Wave Form of Line Voltage Measured in Compensator Test Using Series Reactor

effective welding current that has the desired heat. Assuming that the value of the line voltage supplying the welder drops, the current delivered to the welder by the Ignitron control without the Compensator would be as shown by Curve 3. The starting point would be the same but the magnitude would be decreased. The Compensator functions to advance the starting point of the current flow so that the current has a wave form as shown by Curve 4. The effective (root-mean-square) current of Curve 4 is equal to that of Curve 2. The value of the welding current is then unchanged even though the line voltage has reduced in value. If the line voltage rises, the Compensator reduces the length of time the Ignitron tube conducts current, thereby reducing the current to its original value.

Testing of Compensator

A series of tests were made with the Compensator to demonstrate how well it functioned.

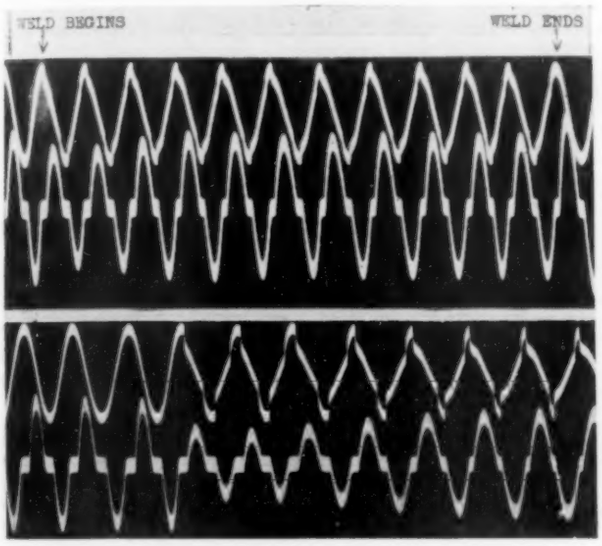


Fig. 12—Oscillograms of Compensator Operation

A—with voltage drop that might be expected in service.
B—with maximum voltage drop
Upper waves—Line voltage
Lower waves—Current to dummy load in compensator having the same wave form as current to spot welder, except energized continuously.

The first set of tests were made by using an autotransformer to reduce the line voltage as shown in Fig. 7. Figures 8 and 9 show curves plotted from the data recorded on these tests. The voltage reductions shown are based on open circuit readings and therefore do not show the actual voltage reductions under load conditions. The load voltages are lower due to line drop and impedance drop in the autotransformer. These tests, however, indicated substantial benefits in weld consistency because of the Compensator.

In order to determine how the Compensator would work when the voltage was reduced coincidentally with the making of a weld, a second series of tests was made using a variable series reactor as shown in the attached schematic wiring diagram, Fig. 10. This simulated the condition that would exist if the voltage were suddenly reduced while making a spot weld. This condition would be created by another welder firing at the same time. Voltages recorded in these tests were obtained by using a pointer stop voltmeter, thus measuring the voltage drop that occurred while the weld was being made.

Even though the load voltages were measured in the

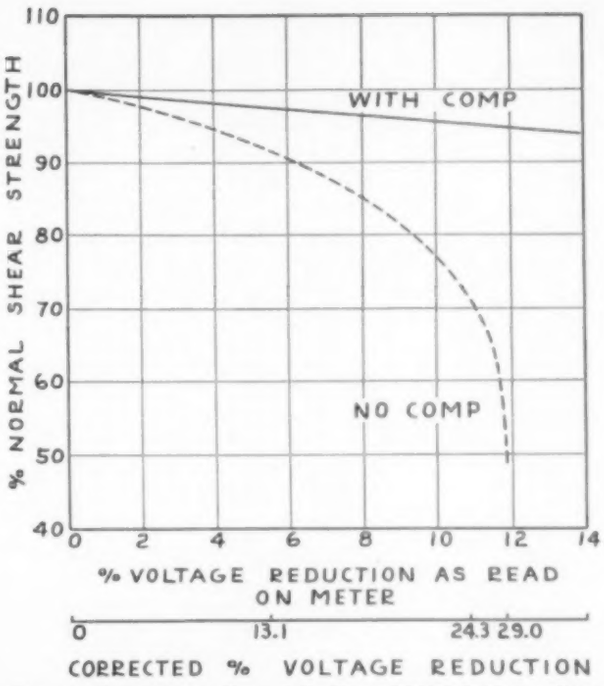


Fig. 13—Compensator Test G. E. Type CR7503-D117 Auxiliary Welding Panel with Series Reactor. 16 Gage Stainless. 12 Cycles

tests with the series reactor, the readings still do not represent the true value of voltage drop because of the distorted wave form of the load voltage. The distorted wave form of the load voltage read in the tests is due to the "phase-shifted" current delivered to the welder by the Ignitron control. The current is conducted for only a portion of each half cycle by the control tubes. This means that the voltage delivered to the control and welder returns to the open circuit value during that period in each half cycle that the tube is not conducting current. The voltage read on the meter is the average (r.m.s.) value for the whole cycle which includes that portion of time during which the welder is open circuited. The voltage read will be higher than the actual voltage during the time that the tube is conducting current. The voltage drop in all cases, when using the series reactor, is then actually greater than the meter indicates. The

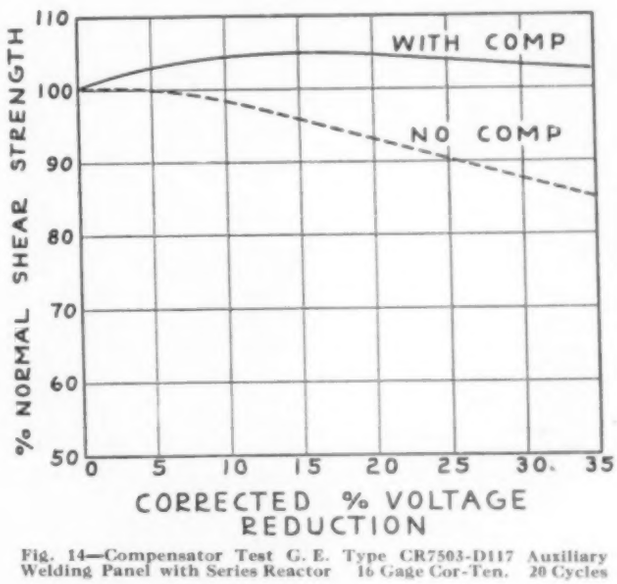


Fig. 14—Compensator Test G. E. Type CR7503-D117 Auxiliary Welding Panel with Series Reactor 16 Gage Cor-Ten. 20 Cycles

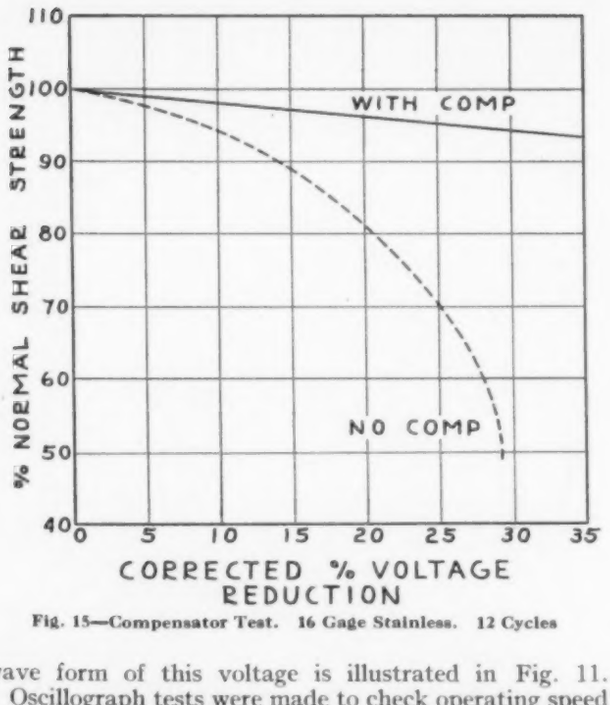


Fig. 15—Compensator Test. 16 Gage Stainless. 12 Cycles

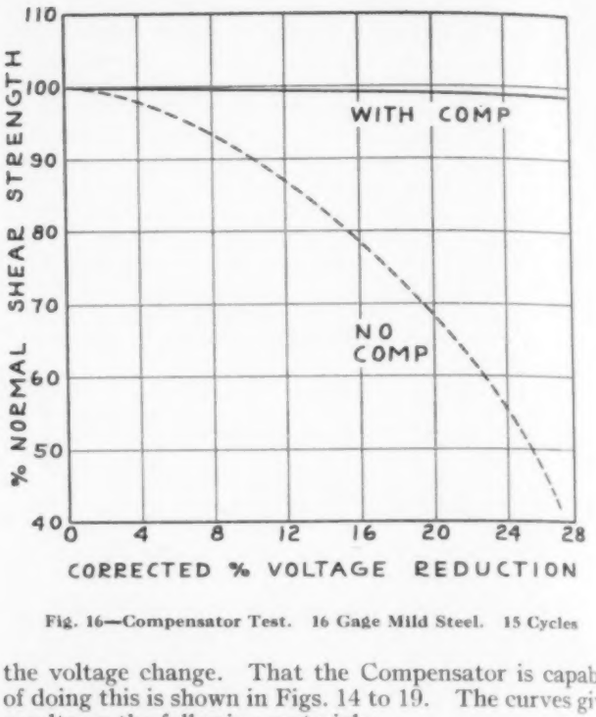


Fig. 16—Compensator Test. 16 Gage Mild Steel. 15 Cycles

wave form of this voltage is illustrated in Fig. 11.

Oscillograph tests were made to check operating speed of the Compensator. The oscillogram (Fig. 12) shows that the phase shift required to restore the current to its normal effective value is completed in two to three cycles.

Figure 13 illustrates results of tests on 16 gage 18–8 stainless steel plotted using voltage reduction as read on the meter. To get the true value of voltage reduction it is necessary to use the shear strengths obtained for the welds, and refer to the shear curves on Figs. 3 and 4 to obtain corresponding current values. The per cent reduction in current is directly proportional to the voltage. The curves in Figs. 14 to 19 were plotted using this method for correcting the per cent voltage reduction values. The corrected voltage is the value that the meter would have read if the welding current had been sinusoidal instead of a distorted wave form.

The sudden voltage drop when using the series reactor requires the Compensator to act quickly to correct for the voltage change. That the Compensator is capable of doing this is shown in Figs. 14 to 19. The curves give results on the following materials:

16 Gage	Cor-Ten	Fig. 14
16 Gage	18–8 stainless	Fig. 15
16 Gage	Mild steel	Fig. 16
18 Gage	Cor-Ten	Fig. 17
19 Gage	18–8 stainless	Fig. 18
18 Gage	Mild steel	Fig. 19

All the above curves were made with the ideal welding current, that is, the highest current that could be used without expulsion of metal. This gives the greatest range for reduction of welding current. The ideal current is not always used, for example, because of electrode wear, shunting of current by previous spots, etc. This means that the setting of the welding current may be on the steeper part of the shear curve. To demonstrate how the Compensator works under these conditions a series of tests was made on 16 gage Cor-Ten steel at various welding currents. Five different current set-

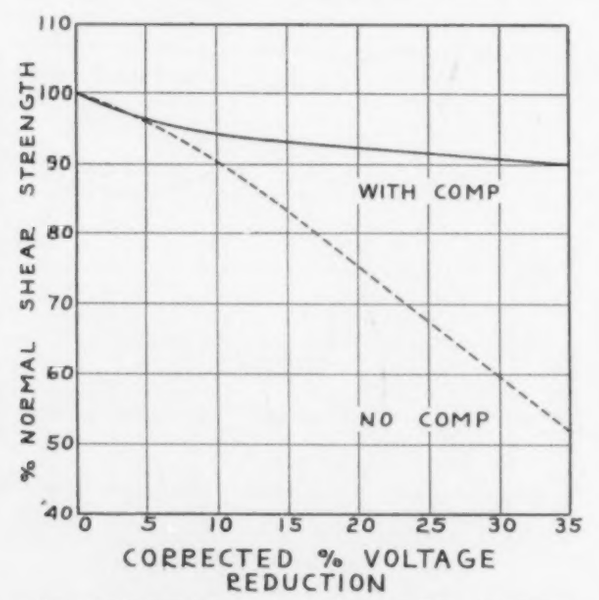


Fig. 17—Compensator Test. 18 Gage Cor-Ten. 12 Cycles

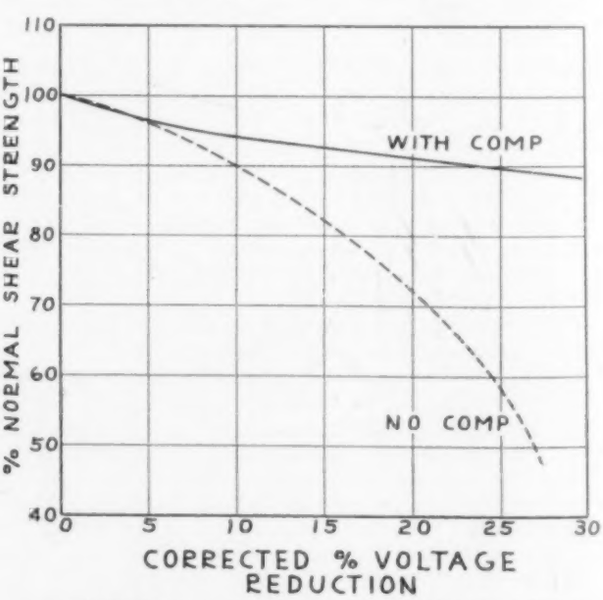


Fig. 18—Compensator Test. 19 Gage Stainless. 8 Cycles

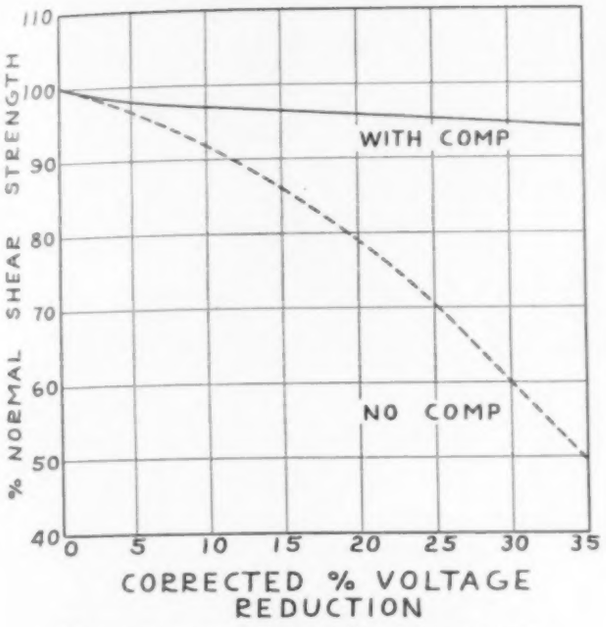


Fig. 19—Compensator Test. 18 Gage Steel. 12 Cycles

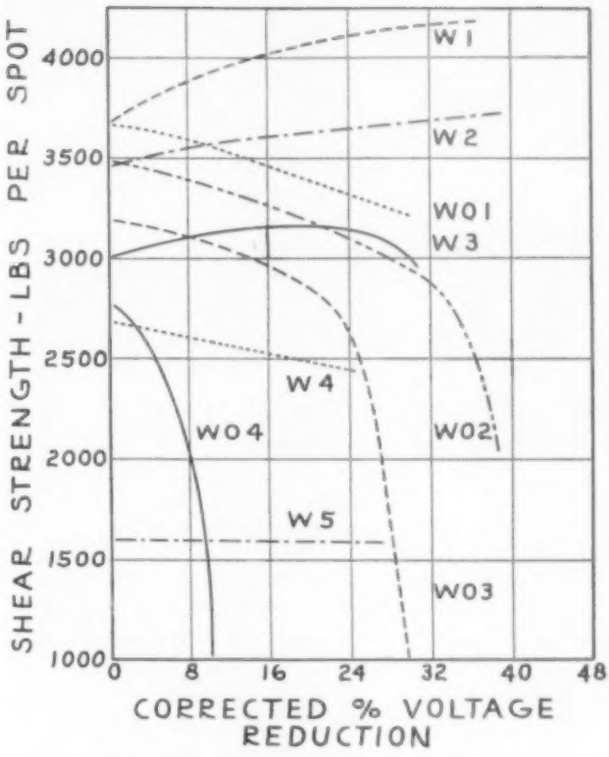


Fig. 20—Compensator Test. 16 Gage Cor-Ten

WO—Without compensator
W—With compensator

tings were used with the Compensator and four without the Compensator. Figure 20 shows that the Compensator helps considerably in maintaining weld strength consistency at all settings of welding current. It will also be noted that for the higher current settings the Compensator slightly overcompensates and for the lower current settings it slightly undercompensates.

The tests that have been made on the Compensator show that satisfactory strength values for spot welds can be maintained even with line voltage reductions amounting to 30% or more. Without the Compensator, a reduction in voltage to this value would produce unacceptable welds. If the line voltage were to be reduced much below this value, the relays in the timer would refuse to function. Therefore, it can be said that the Compensator will maintain satisfactory consistency of welds for voltages within the operating range of the timer.

Acknowledgment

The author wishes to acknowledge and thank Mr. R. F. Johnson for his help in writing and editing this article.

Riveted *vs.* Welded Galvanized and Corrosion Resisting Steel Smoke Pipes*

By H. O. Klinke†

THE tremendous growth in the application of welding to ship construction, both cargo vessels and ships of war, has been confined for the most part to metallic arc welding. The type and thickness of steel used for the hull and interior compartmentation of such vessels has lent itself very advantageously to the metallic arc-welding method and this method today plays a very vital rôle in constructing ships to meet the tremendous demands of our present national emergency.

Resistance welding is less widely used to fabricate certain of the lighter ship assemblies and this method of welding has proved adaptable for the rapid and economical fabrication of many such ship parts.

This paper deals with the fabrication of smoke stacks for war vessels assembled by resistance welding at the Philadelphia Navy Yard. These smoke pipes are of cylindrical or elliptical shape from 25 to 40 feet high and with an approximate diameter varying from 8 to 14 feet. They may be fabricated of galvanized or stainless steel sheet varying in thickness from 0.032 in. to 0.096 in. and are stiffened by flat bars, angles or channels running circumferentially and longitudinally in the interior of the stack.

Formerly, the accepted method of assembling these

* To be presented at the Annual Meeting, A. W. S., Philadelphia, Pa., Oct. 20 to 24, 1941. This paper represents only the personal opinions of the author and in no way reflects the official attitude of the Navy Dept.

† Welding Engineer, U. S. Navy Yard, Philadelphia, Pa.

View of Completed, 35,000 Ton Battleship, USS Washington

smoke pipes was by riveting, but welding has proved itself to be a more economical and faster method.

The resistance welding equipment necessary consists of a pedestal type press welder of a capacity depending upon the total thickness of material that has to be welded. The welder illustrated in Fig. 4 is a 250-kva. RWMA capacity and is equipped with a thyratron repeat type timing unit. A 150-kva. RWMA capacity seam welder is used to seam or intermittently spot weld small gage sheet assemblies. Several push guns are of value in making welds that are inaccessible with the pedestal type equipment and also for use aboard ship. The salient feature of the press welder illustrated in Fig. 4 is the extremely long throat depth of 52 in. as seen in Fig. 2.

A spot weld of the type used in fabricating these stacks consists of a local fusion or joining of the two metals in contact in a small local area directly under the electrodes and the area of this fusion is approximately equivalent to the diameter of the electrodes. No filler material is added in this method of welding, the weld being formed by the localized heating due to the passing of an electric current and the simultaneous application of pressure causing a fusion or bonding of the two metals. Thus, no extraneous metal is added and the weld consists of the same metal as the two parent plates. The fused area is usually an egg-shaped nugget which does not extend to the outer surface of the two plates, and the character of the joint is approximately the same as that of a rivet. In materials of low resistivity the contact resistance of the two surfaces being joined is the main source of the heat and this also acts to form the fused area symmetrically about the contacting surfaces, which is most desirable. Also, in welding plates of low resistivity, this localization of heat at the contact point enables the use of electrodes of the same diameter, irrespective of whether the two plates are of equal or unequal thickness. When welding plate material of high resistivity such as stainless steel, the mass resistance of the combined plates frequently causes the nugget to be located at the middle of the two thicknesses rather than at the contact plane. Hence, if the plates are of unequal thickness the fused nugget may not occur at the junction point of the two plates and no fusion will occur. When welding such material in unequal thicknesses it is, therefore, necessary to use electrodes of unequal diameter so as to locate the fused area at the junction plane of the two plates.

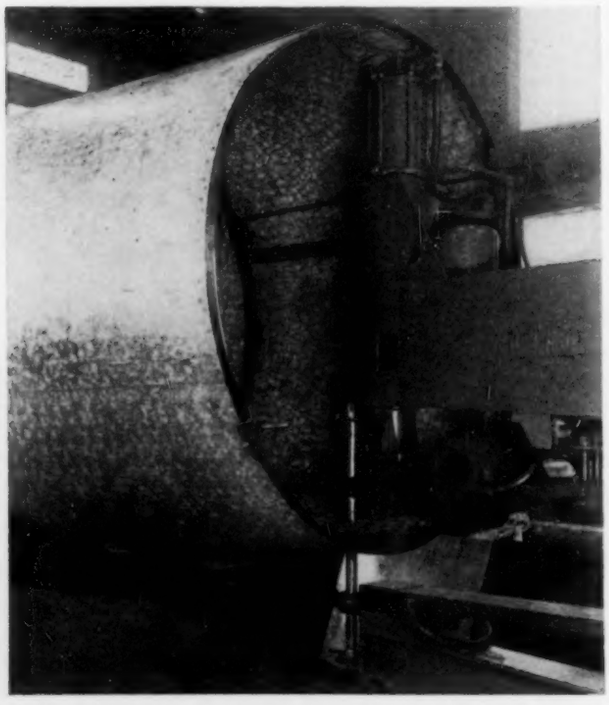


Fig. 1—Galvanized Sheet Metal Destroyer Stack in Throat of Welder

When welding galvanized or corrosion resisting steel it is essential that the corrosion resisting properties of the material be not destroyed by the localized surface heating during the welding operation. In the welding of CRS this may best be done by keeping the duration of current flow below approximately ten cycles so as to avoid carbide precipitation in this material. In the case of galvanized steel the welding pressure and electrode diameters should be so selected that surface heating of the plate does not occur and hence no zinc is lost. All welds illustrated subsequently in this paper were first checked for corrosion resistance by an accelerated salt spray test and found satisfactory.

Figure 1 illustrates the method of welding a galvanized steel stack. The backing ring is $1^1/_2$ in. by $^3/_{16}$ in. black steel as was the longitudinal stiffening bar. As may be seen in the photograph, Fig. 2, the stack is composed of a series of circular segments or rings approximately 3 feet long and are joined together by spot welding to the steel backing ring. The method of support for the stack is also shown in Fig. 2. This type of support enables the stack to be rotated easily when welding the girth joint. Figure 3 shows the completed stack ready for installation on the ship and after painting will present an extremely

Fig. 2—Four Sections of Stack Being Supported in Welder by Overhead Crane

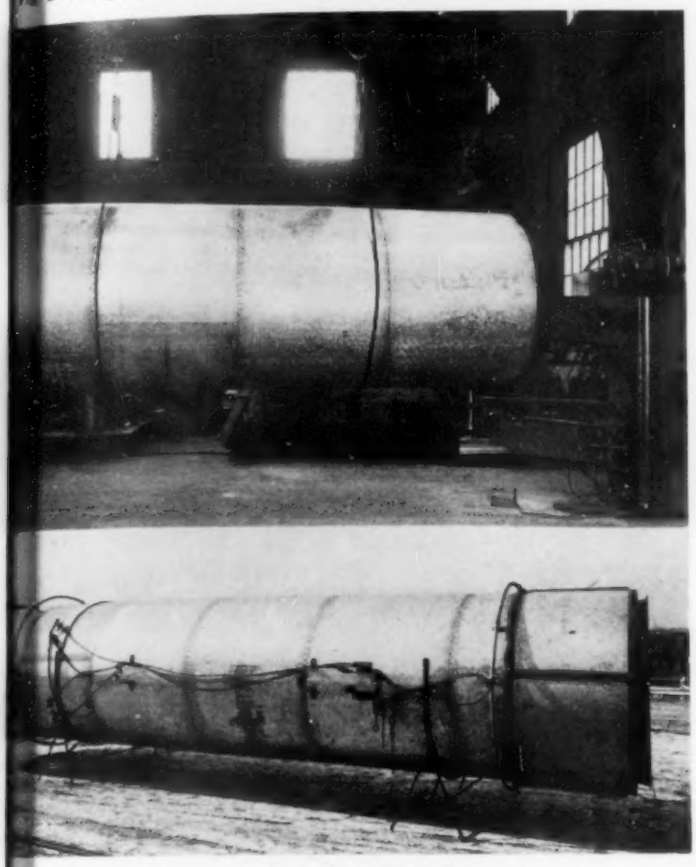


Fig. 3—Completed Destroyer Stack

smooth outer surface unmarred by rivet heads. The smooth outer appearance and lack of distortion obtainable by the resistance welding method of assembly is also clearly shown in this photograph.

Figures 4 through 11 illustrate the fabrication of a very large stainless steel smoke pipe. This stack was approximately 40 feet long, elliptical in cross section and weighed about 12 tons. All joints in this stack and all interior stiffening members were spot welded and after assembly the abutting edges of the outer sheet were arc welded together by a sealing bead to make the stack air-tight and improve its appearance. The major difficulties encountered in the fabrication of such a large assembly by spot welding were the handling of the stacks during the assembly period and the selection of a proper welding sequence to avoid distortion in the completed stack.

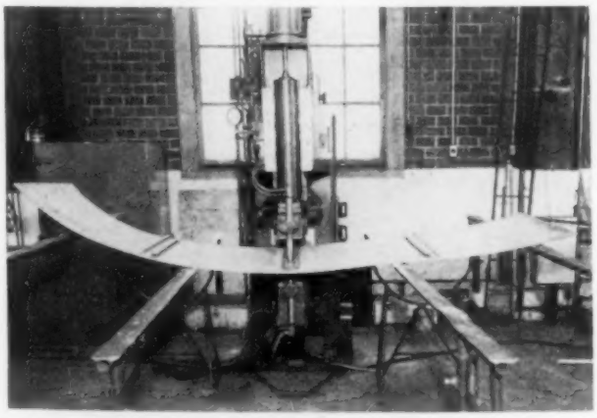


Fig. 4—Formed CRS Channel Being Welded to Single CRS Sheet

The necessity of two welding methods in the assembly of this stack makes the erection sequence doubly difficult. The primary strength joints having been assembled by spot welding, the structure is then rigid, much as a riveted structure would be, and when the abutting edges of the outside sheets are arc welded, considerable distortion is apt to result. Care must be taken to allow for this contraction across the arc-welded seam, by leaving sufficient gap or by assembling the structure with the sheets having been heated.

Figure 4 shows a segment of the initial ring of the stack held in position in the throat of the welder for spot welding a longitudinal formed CRS channel to the wrapper sheet. A partially completed ring section is shown in

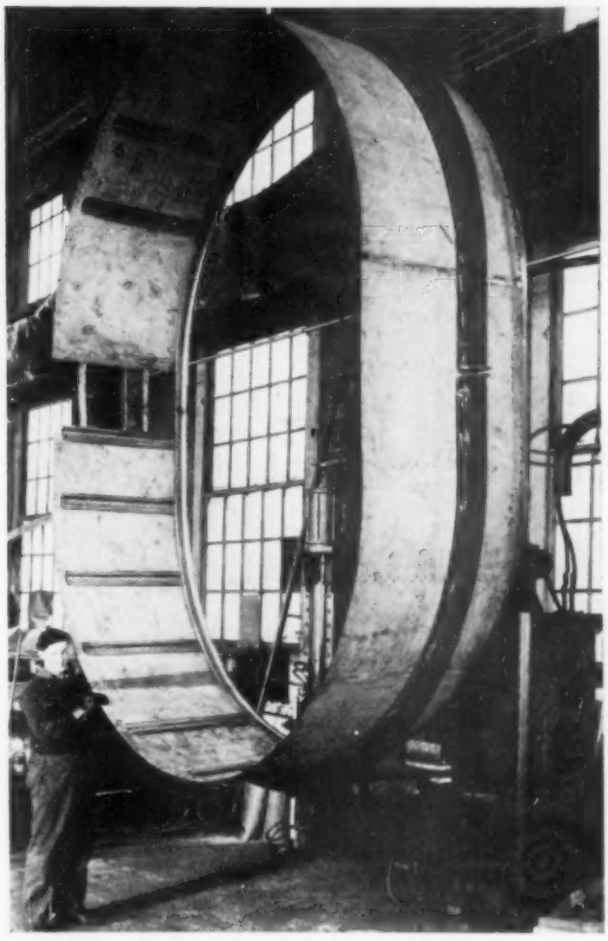
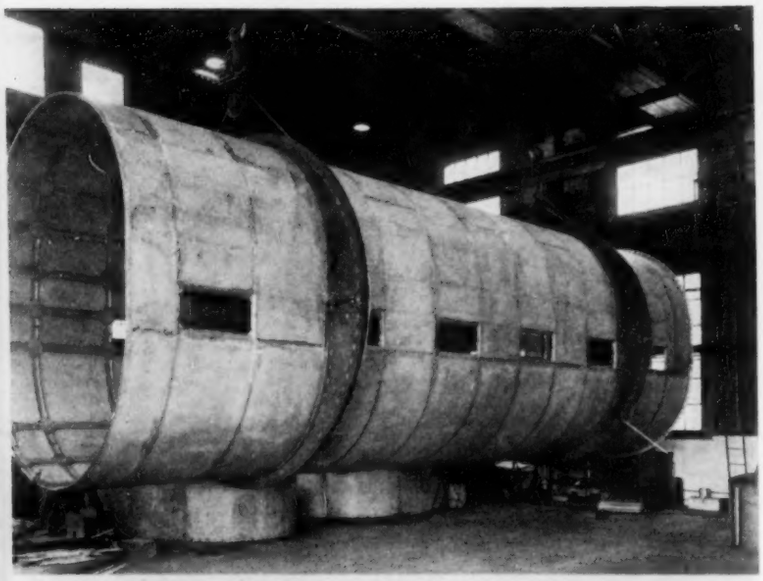


Fig. 5—Ring Segment or Strake of Stack

Fig. 5. This view shows the method of supporting the ring from an overhead crane.

Figure 6 shows the completed inner section of the stack being supported in position for the welding of the lower angle mounting bracket. It will be noted from this photograph that several heavy rings were clasped about the stack over which a supporting cable from the crane hook was passed. These rings are of such shape as to present a circular periphery for the crane sling to aid in rotating the stack. The ring nearest the welder in the photograph indicates how the stack is rotated. A series of pins projecting from this circular ring were acted upon by a bar fastened with a chain to the crane hook, thus

Fig. 6—Completed Inner Section of Stack



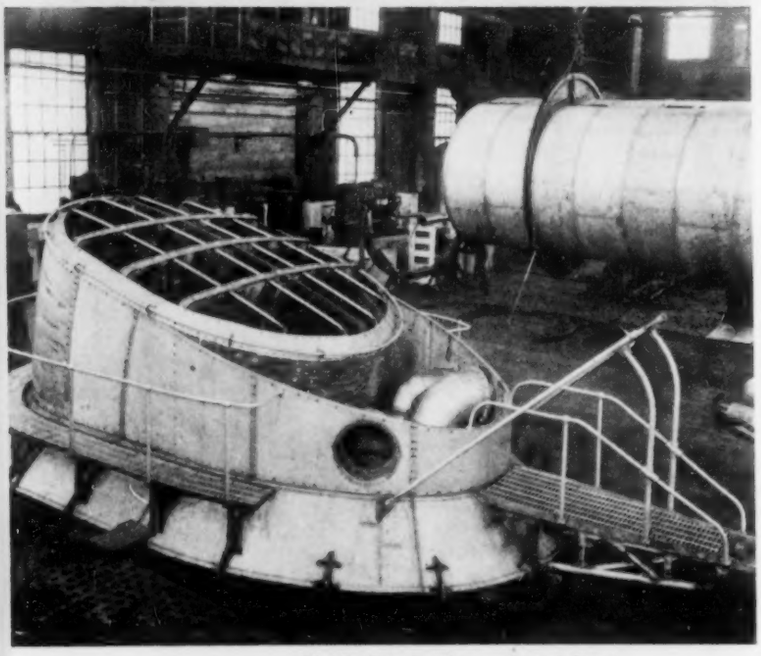


Fig. 7—Top Portion or Cap of Stack

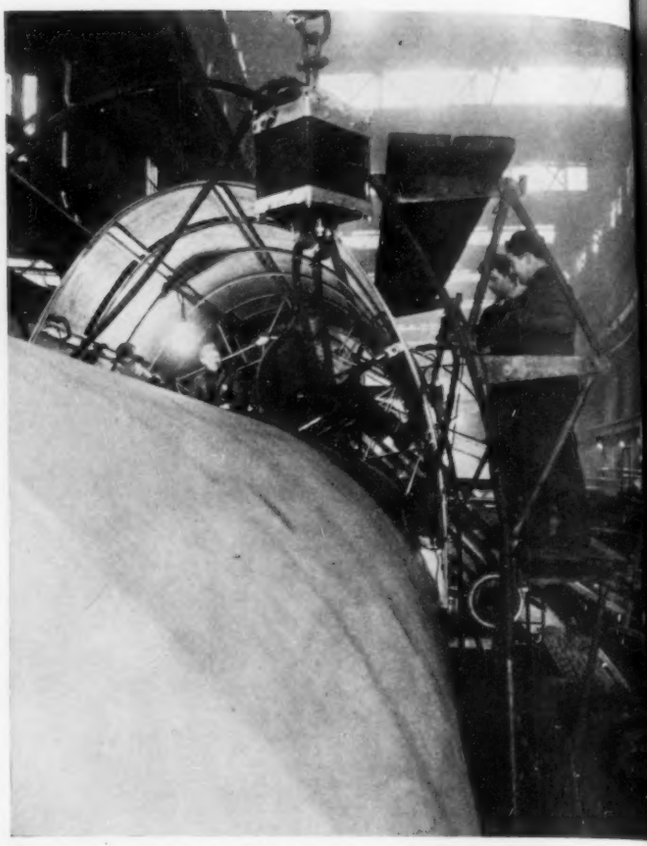


Fig. 8—Outer Envelope or Wrapper Sheet Being Welded by a Push Gun

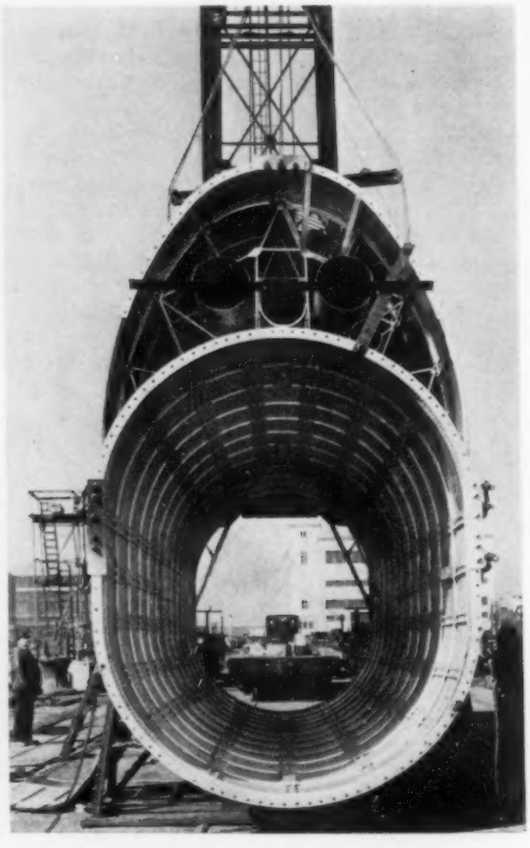


Fig. 9—End View of Completed Stack

giving sufficient leverage to rotate the stack. With this means of support the stack could be raised and lowered, moved in and out, and also rotated so as to present full accessibility for making welds at any point. Also shown in Fig. 6 is the interior of the stack showing the gusset plates, spot welded to the junction points of the circumferential and longitudinal stiffening channels. The circumferential channels were continuous, the longitudinal members being broken. The stack is sufficiently rigid so that two points of support are ample and cause no bending of the stack.

Figure 7 is a view of the top portion of the stack, showing the stack proper and the outer envelope containing several auxiliary exhaust and vent pipes. The pipe structure seen at the rear of the stack is a support for the ship's antenna.

Figure 8 shows the outer envelope being spot welded to the stack by means of a portable push gun. The

stack was placed in a horizontal position on a cradle and the envelope was hoisted in place in 3-foot sections. This welding was done with a 100-kva. transformer and a portable push gun, the circuit being completed on the inner side of the stack by a copper block which was moved along as the welding progressed.

Figure 9 is an end view of the completed stack and Fig. 10 shows the stack being hoisted in place over the inner stack aboard the ship. Figure 11 is a completed view showing the two stacks in place aboard the ship. The first illustration is a view of the completed ship.

Earlier stacks fabricated by riveting were assembled and stiffened in much the same manner except that a rivet replaced each present spot weld. A comparison made as to building time, cost and rigidity of stacks made by the two methods indicates a decided superiority for the welded construction. An additional advantage of the welded stack is the fact that semi-skilled personnel can be successfully used for the operation of the spot-welding equipment whereas riveted construction requires trained craftsmen and skilled supervision to insure satisfactory workmanship.

The advantages of resistance welded fabrication methods can best be epitomized by stating that the Yard is now investigating the possibilities of spot welding the wrought iron inner stack using the repeat or "woodpecker" timing unit recently acquired by the Yard.

Acknowledgment

The author wishes to acknowledge the kind cooperation and assistance of the Yard Management and of Mr. T. P. O'Connor, Master, Mr. E. Wanting, Foreman, Mr. A. Gerber, Quarterman, of the Boiler Shop, and Mr. T. Imholz, Assistant Welding Engineer, all of the Navy Yard, Philadelphia.

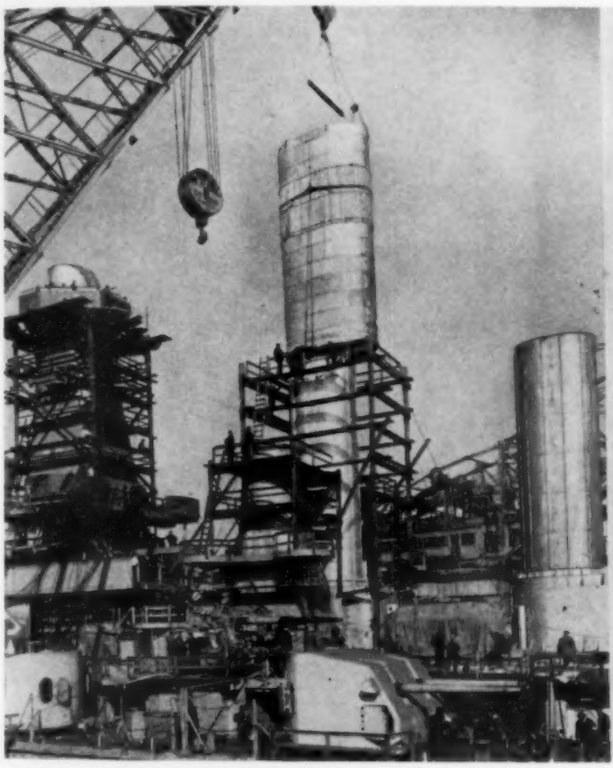


Fig. 10—Stack Being Lowered in Place Over Inner Wrought Iron Stack

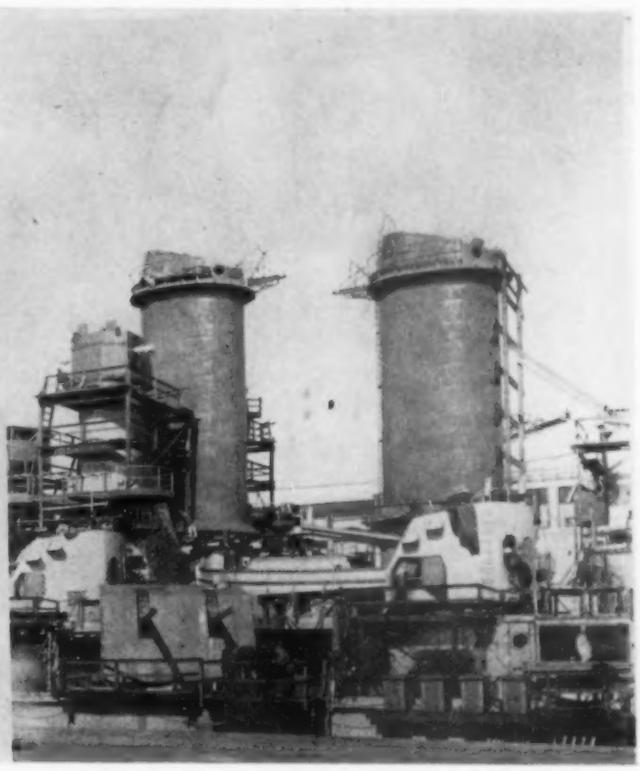


Fig. 11—View of Both Stacks in Place After Painting

ANNUAL BANQUET and DANCE

The Social high-spot of the Annual Meeting is the Banquet at 7 P.M. Thursday evening October 23rd at the Bellevue Stratford Hotel, Philadelphia. In recent years space has been sold out in advance. In order to avoid disappointment, companies are urged to make their table reservations at once. Write to W. A. Terry, General Electric Co., 1405 Locust St., Philadelphia. Price of tickets $5.00. An unusual program of entertainment has been provided.

Fig. 1—Welded Rigid-Frame Bridge of Two 68-Foot Spans Over Wilbur Cross Parkway, Designed by the State Highway Department of Connecticut

Adapting Structural Design and Construction Methods to Welding*

By LaMotte Grover†

TO realize the greatest economy from the use of welding for steel structures, the materials of construction, the designing and detailing, the layout and general facilities for fabrication and erection, the shop procedures and general methods of construction, and the organization of personnel, must all be adapted to welded construction. A shortcoming in one or more of these respects is nearly always found to be the principal reason for one contractor or fabricator failing to realize as much advantage from welding as others do in the same class of work.

In some instances, unreasonable cost burdens have been imposed upon welded construction by requirements for unnecessarily elaborate and extensive qualification and acceptance tests; also by costly code and specification provisions that add nothing to the assurance of reliable construction. Such requirements are usually imposed by someone who is not completely informed about correct welding practices and who seeks to protect himself against difficulties by including in his specifications everything in the archives of welding literature that appears to constitute a safeguard, even though it may have been discarded long ago as unnecessary and probably ineffective, as well. In a few cases, inspectors, inexperienced in welded construction and prompted by these same motives, have imposed undue hardships upon contractors.

An insufficient supply of properly trained welding operators to keep pace with the rapid increase in the use of welding, and the frequent shifting of welding operators from one employer to another, as a consequence, have caused much annoyance to steel fabricators in the development of welding in their shops. However, when the peak of defense construction has passed there will no doubt be an adequate number of excellent operators available for normal construction and industrial work, because of the large number recently trained.

Organization for Welding

The question is often asked by the prospective user of welding, just what has taken place in well-organized welding shops and field organizations that now makes it possible to assure good welded construction, whereas it is undeniable that there have been welding failures, and at one time it was difficult to predict results with certainty under comparatively unfavorable circumstances.

Fig. 2—Welded Rigid-Frame Construction, Designed and Constructed by Leach Steel Corporation of Rochester, New York, for Eastman Factory Building, Provides Interior of Clean-Cut, Pleasing Appearance with No Obstructions to Efficient Working Operations

* To be presented at the Annual Meeting, A. W. S., Philadelphia, Pa., Oct. 20 to 24, 1941.

† Structural Welding Engineer, Air Reduction Sales Co., New York.

Fig. 3—An Inexpensive Device Was Used to Position the Column-and-Knee Sections of the Eastman Rigid-Frame Building, for Balanced Deposition of Welding in the Most Convenient Position

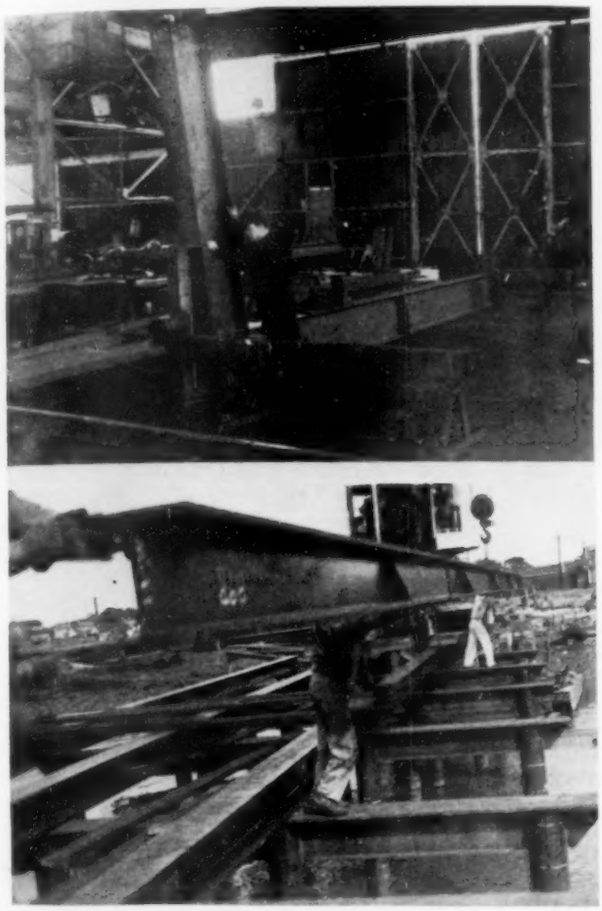


Fig. 4—Welded, Double-Track, Main-Line, Continuous-Span Trestle of 250-Foot Length and Class E 60 Loading, Designed by the Florida East-Coast Railway

The answer is that reliable procedures for welding have now been developed and have become quite well standardized for all ordinary applications of welding. Since the fundamental principles of welding for any general class of steels are the same, regardless of type of structure involved, experience and research in many fields have been available as a basis for establishing correct procedures. Also a standard and reliable method has been established by the AMERICAN WELDING SOCIETY for qualifying proposed new welding procedures and their use in new applications involving different materials or changes in other important factors.

With standard proved procedures in use, and proper control to insure that these procedures are followed, results can be predicted with certainty. Much of the elaborate testing that was used during the experimental stage of welding has thus become unnecessary and its cost has been eliminated by well-advised engineers.

These circumstances have led to a changed concept of organization and responsibility for welding, which has been found to increase the economy of welding very greatly by eliminating confusion and speeding up the work. At one time it was common practice to delegate all responsibility for the welding to the operators themselves; and those supposed to be in responsible charge did not profess to know anything about welding. The welding operator was required to choose the electrode and to determine all the details of the welding operation for each job assigned to him. This was unfair, for one reason, because he did not have control of all factors involved, such as the method and accuracy of preparing the material. Also, if the details were such as to make good welding very difficult, he just had to make the best of it and take the blame for adverse results, or pass the buck on to something—usually the electrode or the welding machine—the only things available. Under these circumstances welding operators really should have been qualified as welding engineers, as well as skilled workmen, and in some kinds of work, as metallurgists and designing engineers, also.

In the well-organized plant today, a welding engineer or superintendent is now placed in responsible charge. The choice of electrodes and equipment, all details of the welding procedure and everything that affects it, are worked out in cooperation between the shop and the engineering department. The welding operators are required to follow the standard practices established for the shop and they are held responsible only for their skill in manipulating the electrode, or the torch in the case of gas welding. Their qualification is therefore comparatively simple to prove they can obtain thorough fusion and root penetration and make sound, properly shaped welds. Since the strength of the welds depends upon the materials and the welding procedure, the new AMERICAN WELDING SOCIETY operator qualification procedure properly includes no strength tests.

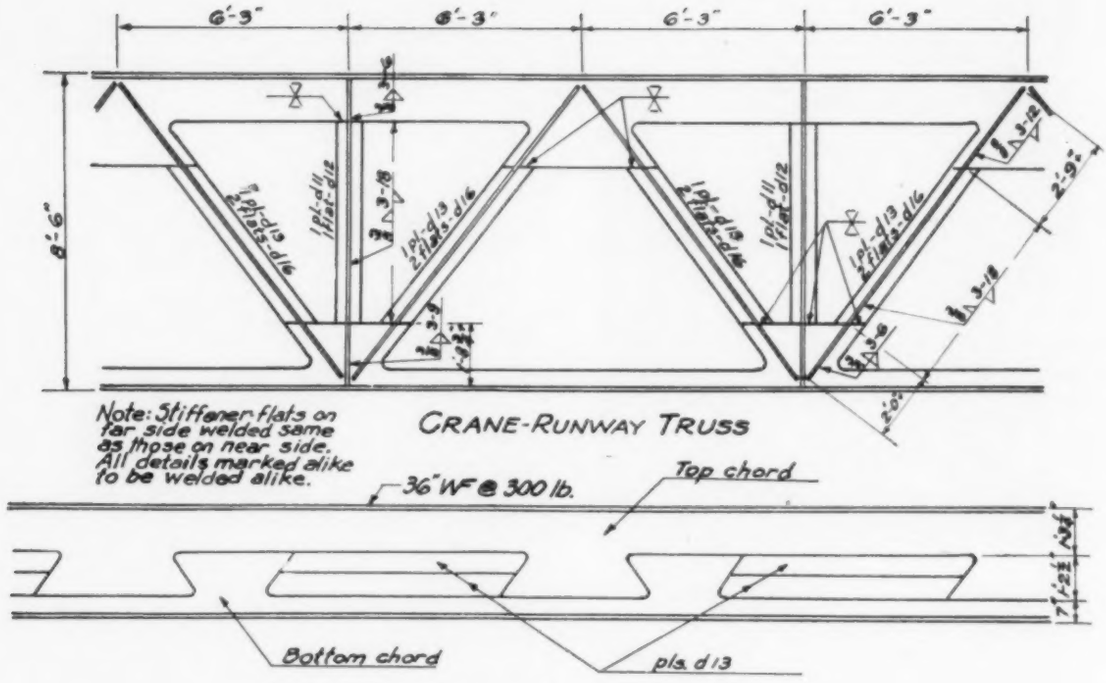
Materials of Construction

Substantial improvements in electrodes, even since the adoption of shielded-arc electrodes for all important work, have done much to facilitate reliable welding and decrease its cost. The standardization of types of electrodes in the A. W. S.-A. S. T. M. joint specification, A233-40T has helped to eliminate confusion. Having been agreed upon by all responsible manufacturers, it is evidence of enough similarity in electrode products that operators changing from one kind of shielded-arc electrode to another need not be requalified.

By taking full advantage of the various types of electrodes available, to choose the one most appropriate for any application, a substantial amount of cost can be saved. For example, many shops position practically all their work for flat or horizontal fillet welding (Figs. 3 and 8), but stop short of realizing full economy because they do not use high-melting-rate electrodes such as those of A. W. S.-A. S. T. M. Classification E6020, which are faster electrodes than the all-position types and facilitate the making of smooth welds of the best physical properties. Welds made with these electrodes remain in the hot plastic stage longer, which permits shrinkage to be absorbed, and thus any tendency toward distortion and high shrinkage stress is reduced.

However, where a very substantial amount of vertical or overhead welding is encountered by an operator along with the down-hand welding, it is not usually practical to have him change the type of electrode continually. In erecting steel structures a substantial amount of vertical welding can hardly be avoided.

A mistake naturally made quite often in choosing an electrode for welding high-strength structural steels, is to use a special high-strength electrode, even though all the welds are either fillet welds designed for unit stresses that have been set up for welding ordinary steel structures, or butt welds at points of low stress. There is no need for the additional strength thus obtained and some ductility has to be sacrificed, and along with it some of the ability of the joints to deform locally and adjust themselves to strains during fabrication and erection.



CUTTING DIAGRAM

Fig. 5—Crane Runway Truss of Design Specially Adapted to Welding, Constructed by Bethlehem Steel Co. for One of Their Beam Storage Yards

If the steel is at all difficult to weld in the application involved, the difficulty is likely to be increased somewhat by the use of such special electrodes.

If a butt-weld joint of 100% strength efficiency is required in a high-strength steel, it may be necessary to use a high-strength electrode, although butt welds made in narrow grooves, as well as fillet welds of sizes most common in structural work, made with ordinary electrodes of the A. W. S.-A. S. T. M. Classification E60 series, will pick up enough alloying elements from a high-strength base metal to raise their strength very substantially.

Silicon steel as now manufactured is not recommended for welded structures because of its high carbon and its lack of uniformity in chemical composition. Aside from the question of reliability of welding, silicon steel is not an economical material for welded construction. Under circumstances where a high-strength steel is justified, the sections are very likely to be heavy enough that at least special, more expensive welding procedures, such as supplementary heating before and during welding, will be required to avoid brittleness. German technicians, as well as engineers in this country, have had trouble in welding steels of this kind.

American technicians eventually may find it economical to develop a low-cost high-strength structural steel of good, controlled weldability, as the Germans seem to have done now. In the meantime, if high-strength steel is required for welded structures, it should be ordered to conform to the Tentative Specifications for Low-Alloy Structural Steel of the A. S. T. M., now accepted by Committee A-1; and it should be specified to be suitable for welding. If for some reason welding on silicon steel is unavoidable, low carbon steel electrodes of the A. W. S.-A. S. T. M. Classification series E60 are the most appropriate from a technical welding viewpoint.

Thousands of tons of A. S. T. M. A-7 standard carbon structural steel have been used in welded construction without difficulty. In a few exceptional cases where very thick material and unfavorable circumstances have been involved, some special precautions have been necessary because of the higher carbon required in thicker material to meet the specified physical test requirements.

Although standard A-7 steel, with no specified limits for carbon and manganese, is considered satisfactory in all respects for welded building construction, consideration for the dynamic loading of bridges has resulted in the placing of special limitations on carbon and manganese in the AMERICAN WELDING SOCIETY Bridge Specifications, to rule out the occasional heats of steel in which these elements might run higher than ordinarily, and thereby necessitate special refinements in welding procedure to avoid loss in ductility. The new 1941 edition of these specifications contains a supplemental provision which modifies the A. S. T. M. A-7 specification to conform to a proposed revision of A-7 that is now being studied by the A. S. T. M.; it prescribes definite limitations on carbon and manganese. To make it a practical specification that steel mills can meet without an extra and without delay, a slight reduction in tensile strength and yield point is permitted as the thickness of material increases; but the reduction is not great enough to warrant a decrease in working stresses.

The trend is toward the adoption of specifications for nearly all steels that will assure their weldability with the most simple, economical welding procedures; because, even in riveted construction certain details are customarily welded now, and it is most probable that future alterations, repairs and additions will be made almost entirely by welding.

Design

Much has been written about exercising original thought in welded design rather than blindly following details and precedents developed for other construction

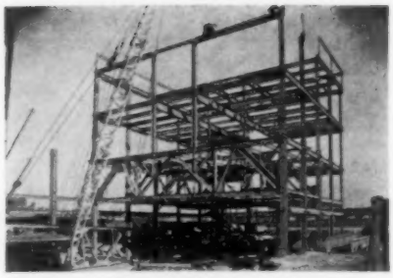


Fig. 6—Reduced Size of Gusset Plates, Made Possible by Welding This 19-Ton Locker-Room Truss of the Benjamin Franklin High School, Facilitated Obtaining Clearances for Doorways Through the Truss. Designed by the Bureau of Construction of the New York City Board of Education and Erected by Lehigh Construction Company, New York, N. Y.

methods. A good example of ingenuity in welded bridge design is the double-track, main-line, continuous-span trestle of 250-ft. length and Class E60 loading of Fig. 4. T-Section caps, made by splitting 27-in.-wide flange beams, are welded in slots cut in the heads of the 10-in. pipe piles. The entire deck of the bridge, including T-section diagonal laterals, acts as a horizontal truss to carry lateral forces to the end bents, thus permitting the elimination of sway bracing in the intermediate bents.

The fact that the form and weights of most rolled structural sections have been adopted from experience in riveted construction has resulted in some inconvenience. Eventually, the demand for sections especially suitable for welding will no doubt result in their being rolled regularly. In the meantime, the gas cutting torch has made it practical to produce T's by splitting steel beams, to alter other sections, and to prepare plate material economically for welded construction.

Most engineers now know that ordinary structural steel can be cut, and edges of material beveled or shaped for butt-weld grooves with an oxyacetylene torch, without any unusual procedure requirements or subsequent treatment of such edges, other than brushing off the loose scale that results from the cutting. (See report of Committee on Oxygen Cutting of Steel of the American Society of Civil Engineers, *Proceedings* April 1940, p. 627; also, report on "The Effect of Flame Cutting on Steel," of the International Acetylene Association.) A special procedure is advisable in gas cutting high carbon or silicon steel and some of the alloy steels, particularly those that harden considerably with rapid cooling and therefore are also more difficult to weld.

One of the most important things that the designer must do is to keep in mind the general shop and erection operations involved in executing his design. This is especially important when some of the joints or details are welded while others are bolted or riveted. It is still a very common error for a small amount of both welding and punching and riveting to be called for on the same piece, thereby necessitating extra shop or field operations and expensive handling of heavy pieces, without enough material saved to compensate for the extra expense.

When bolts or rivets are used along with welding, it is desirable to at least eliminate all holes near critical sections, to make the gross section effective. A comparatively large number of welded details used on such a member, however, may in themselves save enough material to justify any extra shop handling involved.

Often welding and gas cutting can be utilized to eliminate more expensive shop operations such as drilling, milling or punching. Welded cover plates and web stiffeners for rolled beam spans have been utilized to good advantage even when riveted field splices are used, although the use of welded field splices improves the economy of the shop work by eliminating all handling and punching or drilling for making rivet holes.

Low bids on welded alternatives for simple, beam and column tier buildings have shown that experienced fabricators and erectors can save some money by using welding in this class of construction. Greater savings are possible when trusses, girders or cover-plated beams are required to span comparatively large areas. When continuous or rigid-frame construction is used and full advantage is taken of the natural adaptability of welding to form economical and effective rigid joints and connections, then the greatest opportunities for cost savings are presented.

Aside from the attractive economy in construction and maintenance of welded rigid-frame mill-type buildings, their efficient clean-cut, streamlined interiors of pleasing appearance (Fig. 2), with no maze of overhead steel work to interfere with efficient lighting, are coming into demand rapidly in the same way that industry demands neat, streamlined equipment for operation in its buildings. This kind of framing is particularly efficient for types of industrial and defense construction that are now being carried out on a large scale, where no one can predict what changes in working operations may have to be made in the future, and it is particularly important to avoid interior columns that might be even a more serious obstacle to efficient operations in the future than at present.

In details where severe impact or maximum allowable stresses repeated many times, are involved, it is good design practice to provide smooth, curved transitions between members, to avoid local stress concentrations at sharp bends or corners. This involves some added expense but the work is simplified and facilitated greatly by the use of welding. Such details have been used in railway bridges.

In highway bridges (Fig. 1) carrying mostly passenger vehicles with only occasional heavy loads, it is questionable whether the additional expense for curved haunches in the main members would be justified, unless they are required to fulfil architectural objectives.

In statically loaded structures like buildings, such a refinement used solely to provide easy transitions in stress paths is seldom justified, and "square knees" are often used for rigid frames (Fig. 2). If the steel remains exposed to view, the small extra expense for curved lines, as in the corners of rigid frames, may be warranted to attain a smoother streamlined appearance for some kinds of buildings.

Although some details developed for riveting happen to be suitable also for welding, experience shows that, in

Fig. 7—Assembling and Tack Welding Girders at Lehigh Structural Steel Company, Allentown, Pa., for a Connecticut Highway Bridge

general, the amount of cost that can be saved by welding is proportionate to the amount of ingenuity that has been exercised to adapt details especially to welding. For example, now that welded girders are made up of a web plate and two flat flange plates fillet welded together, with no more than one additional cover plate per flange, at the most, welded girders have provided remarkable cost savings. In earlier welded girder designs, patterned after riveted members, with flange angles and several cover plates, the design was technically poor and nothing was saved by using welding.

In light welded trusses where T-sections have been substituted for chord angles, but angles connected by one leg are still used for web members, the saving in cost is somewhat less than in plate girder construction, particularly if the capacity of an angle with one leg connected by welding is penalized in accordance with specifications for riveted joints which does not seem to be entirely justified. If the web member angles can be placed with the heel outward and both legs connected by fillet welds, their sections can be utilized more fully. When a larger supply of regularly rolled structural T's is made available by steel mills they will prove useful in many places. Flat bars, stayed at sufficient intervals to prevent vibration, often can be used efficiently for tension diagonals in small trusses. Pipe or tubular sections may find extensive uses as compression struts, laterals and bracing members because they have the same stiffness about all axes, and with welding, end connections can be made easily.

An excellent example of ingenuity and original thought in adapting truss details to welded fabrication is the design shown in Fig. 5, prepared by the Construction Division of the Bethlehem Steel Company and used several years ago in the construction of a double crane runway in one of their beam storage yards.

A 36-in. x 300-lb. wide flange rolled beam was accurately split by gas cutting, as shown in the cutting diagram, and each of the modified T-sections thus produced was used for one of the chords of a truss 8 ft. 6 in. in depth. This scheme permitted the material to be divided between the two chords in such a way as to produce a section for each one with appropriate area and other properties.

The loose plates cut out of the web by the same operation were used in the web members of the truss, with their ends butt welded to the chord members. In this manner advantage was taken of the greater efficiency of butt welds, as compared with fillet welds, for withstanding stresses from dynamic loading. Also, the details in the vicinity of the panel points could in this way be formed to provide smooth stress paths, conducive to high fatigue and impact resistance; and the butt welds could be located at some distance from the panel points, removed from the influence of secondary stresses, and in a position where they could be made easily.

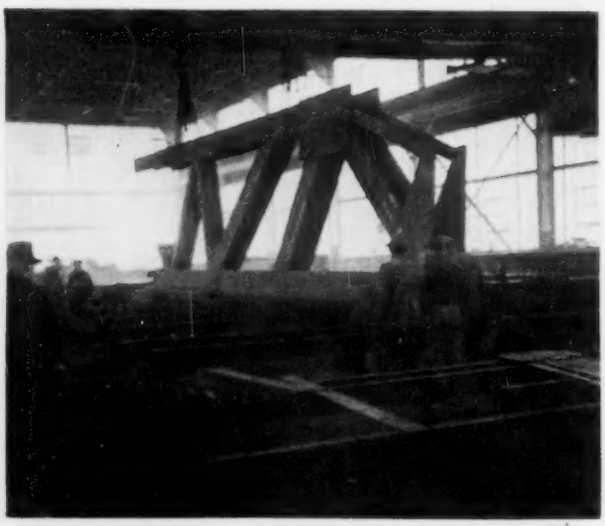


Fig. 8—Turning Over a Heavy Truss Section to Permit Balanced Deposition of Weld Metal in the Flat and Horizontal Positions

Two longitudinal stiffener bars were fillet welded to each diagonal web member of the truss to produce a "star" cross section. Each vertical member was converted to a T-section by adding one longitudinal stiffener.

Heavy welded trusses patterned rather closely after riveted prototypes have shown less direct cost savings than lighter welded trusses, but the reduction in size of gusset plates made possible by welding has facilitated the obtaining of clearances for door openings through such trusses in building construction (Fig. 6). Also, secondary stresses are reduced by using more compact connections. Although these stresses are often of little importance because of their self-limiting nature, they are surely a matter for concern when gusset plates on opposite chords of a truss have to be made so large to develop the connected members, that the plates almost meet.

In general, the maximum economical span length for girders, as compared with trusses, is somewhat greater in welded construction than for riveted work.

Shop and Erection Methods

In the same way that details of design must be adapted to welding to attain the best economy, general methods in shop fabrication and erection have to be altered somewhat also.

When a large expensive piece of equipment, such as a multiple punch and automatic spacer, is not working at full capacity, a shop with such equipment is tempted to make use of it to punch a few holes for fitting up bolts in welded assemblies, because it has always been customary to utilize holes in main material for fitting up. It often results that the cost of moving the material to and from the machine is greater than that for fitting up by means of temporary auxiliary tack-welded lugs and bolts, or cleats, clamps and other devices used by fabricators who have developed such special methods of assemblage. Where a few holes in main material for fitting up bolts are almost indispensable, they can be made by piercing with a gas torch.

In the construction of welded mill buildings, some fabricators and erectors are finding it economical to eliminate all holes for erection bolts, at least in the heavier pieces that are expensive to handle in the shop. Also light members like purlins and girts are erected without bolts, a tack welder working along with the erection crew. The same general scheme has been practiced quite extensively in some areas of the country for tier building erection. Special inexpensive erection seats have been used effectively to eliminate the cost of punching holes for erection bolts.

In assembling trusses for which there is a considerable amount of duplication, the parts are usually aligned and fitted properly in a jig and then tacked together, thus eliminating the need for fitting up bolts.

When there is less duplication, as for the fabrication of the girders of the rigid frame bridge of Figs. 1 and 7, the component parts can be easily blocked up and held together in correct position during tack welding, by

means of clamps, short pieces of angle sections and yokes, the work being laid out by templates or directly on the individual parts by means of scribe lines.

Practically all structural shops position their work for down-hand welding (flat welds and horizontal fillets). Many of them are adopting Class E6020 and E6030 electrodes to attain greater speed and efficiency, and there is a continually increased trend toward the use of a.c. welding in combination with larger diameter electrodes of these classifications, for shop work. With a.c. welding and these high-melting-rate electrodes, the most convenient sequence and direction of welding can be used without disturbance from magnetic flare and with less tendency of the work to distort.

For positioning the rigid-frame post-and-knee section of Fig. 3, so the welding would all be down-hand and the heat of welding could be balanced, a pipe trunnion and strut were attached to the piece so the section could be rotated about its gravity axis with little effort. A similar arrangement has been used efficiently for welding girders, even when little duplication is involved.

Usually jib cranes or overhead cranes are used to turn pieces in positioning them on a welding floor or skids, or on temporary props (Fig. 8). If the service of a crane is devoted exclusively to the piece involved, it can be used effectively with a chain hoist to assist in supporting the piece in the most convenient position for welding.

Some structural fabricators are making use of mechanical positioners for welding bridge pedestals, rockers and other weldments that require a great deal of turning into various positions.

In most parts of the country there is enough favorable weather so that fabricating shops can carry out a great deal of fabrication by welding and gas cutting in their shop yards, after making use of the shop equipment in the preparation of material. There is often a yard crane that is not working full time and can be used for handling and turning the pieces. In this way the capacity of a shop can be increased quickly in times of emergency such as the present, and with only a small additional expenditure for equipment.

Welding is a most versatile method of steel fabrication. As design and construction methods continue to become better adapted to welding, even greater cost savings may be expected from its use.

Fusion Welding as Applied to Locomotive Construction*

By Arthur J. Raymo†

THE building of railway motive power equipment is second only to shipbuilding in a heritage of skilled craftsmanship that has established around the industry a tradition of perfection of materials, methods of construction, and workmanship, that never fails to awe and inspire as we see each new engine take its place in a transportation system that is called upon unceasingly for new and greater achievements.

The time-proven methods of construction which characterize the locomotive building industry command utmost respect, if for no reason than that proposed new methods have to be unusually meritorious and worthwhile in order to supplant accepted practice.

The use of fusion welding is now a recognized method of construction in the art of building locomotives and, even though not yet wholly accepted, it is quite safe to predict that the use of welding will continue to be extended, and in time will supplant all riveting. This method of fabrication will also contribute to the replacement of castings in many instances by making possible the substitution of more economical and serviceable plate weldments.

It is not the purpose of this paper to argue the relative merits of welded construction and riveted construction, or to challenge the continued use of castings, but merely to set forth actual and satisfactory current applications of the use of electric arc welding and to indicate design and construction method trends.

The use of electric arc welding has been found to be so adaptable in the possibilities of its proper applications that separate review will herein be made of the construction of steam, diesel and electric locomotives in the respective order named.

The largest component part of the steam locomotive is the boiler and is also the part which literally demands welded construction in order to develop its maximum effectiveness. As yet the boiler remains essentially of riveted construction, though the welding of such parts as the firebox, siphons, flues, stay-bolt sleeves, feed water heater chamber, and smoke box is accepted as standard practice and as wholly satisfactory.

More recent additions to this group of welded boiler parts are the water space frame and fire brick arch support. Of these two, particular mention is made of the water space frame, which is made up of sections flame-cut from plate or from bar stock. Not only has it been found possible to build this type of mud ring in any size at a cost less than that of a casting, but there has also been total elimination of delays due to rejections of castings found faulty at the time of machining. Assurance of a perfectly sound mud ring, together with the possibility of welding the ring to the fire-box side sheets, has also made possible a 50% reduction of the rivets normally used in making the water leg—mud ring joints tight.

It, therefore, becomes evident that there is not a great deal of the boiler left to weld in order to make it an all-welded structure. The welding of the longitudinal and circumferential joints and the attachment of the steam dome can hardly be regarded as problems that will present any real difficulties.

The cost of a welded boiler will be less than a riveted vessel after facilities for welded fabrication have been installed and workmen have been educated to the most efficient use of such equipment. It is a fallacy to argue

* To be presented at the Annual Meeting, A. W. S., Philadelphia, Pa., October 20 to 24, 1941.

† Supervisor of Welding, The Baldwin Locomotive Works, Philadelphia, Pa.

the lesser cost of welded construction when nothing more than a welding machine is provided to replace all other tools and facilities common to riveted construction. Thus the bull riveting pits and towers would be replaced with rolls for turning the barrel of the boiler so that all welding could be done in the flat position, and X-ray examination would replace caulking of joints.

Such a boiler would be a single pressure-tight unit with a minimum possibility and probability of leakage or failure during its normal service period. However, it remains that completely welded construction is not accepted practice today, and this appears to be due to a spirit of conservatism and good judgment based upon knowledge of a lot of poor welding done in days when lesser facilities for good workmanship were available.

Today we have better knowledge of steels, better welding machines, better electrodes and better skilled welders too, so that, with the added facilities of X-ray examination and stress relief annealing furnaces, there is no reason to believe that the all-welded boiler will not come into its own and find general acceptance in the very near future.

In passing to other parts of the steam locomotive we find that the use of welding has been extended in an ever-increasing manner because it has not only proved to be most economical but also most satisfactory from a structural standpoint.

On the top side we find the cab and sand dome of all-welded construction and wholly accepted as the best way of building.

On the under side we find an all-welded frame and all-welded component units such as pilot, snow plow, truck, cylinders, driving wheels, roller bearing housings, reverse shafts, crossties and ash pan.

The fabrication of these component parts by welding is particularly advantageous when there are but single engines to build, as pattern costs can thus be completely eliminated.

Such items as pilot, truck, pedestal crosstie, valve motion crosstie, guide bearer crosstie and front furnace crosstie are very simple plate and shape assemblies, also having the advantage of requiring much less machining than comparable castings.

The development of the plate cylinder weldment is deserving of particular mention in that it heralds the time when a cast set of cylinders for service replacement will be only something to reminisce about.

We dared to approach this development by first welding on the back head of the cylinder, but such a half-measure has proved merely a gesture indicating the direction in which to proceed, and the next step will unquestionably be an integral cylinder and underframe unit, a counterpart of the casting we now know but with none of its faults.

A more fertile field for rapid extension of the use of welding has been in the construction of the tender. The sufficiency and merit of this type of tender construction is now so well established that it is only mentioned in order to record the application.

In most instances the tender frames are now cast. However, we find it possible to fabricate water bottoms in competition with castings of such type and believe that a superior product is actually produced.

Welding procedure practices associated with tender construction with view to minimizing unsightly wrinkles in the side sheets are being improved upon continually, and today the side plates of the average welded tank actually have fewer waves and buckles than the riveted structures.

The applications of welding thus far reviewed are believed to be amply indicative of the trend toward a more universal use of the method of fabrication, and it is even more encouraging to note that there is a growing degree of receptiveness to the new order on the part of those who have felt more conservatively inclined in the past.

We have even more clean cut evidence of the recognition of the possibilities of welded fabrication on the part of the designers who have given us the diesel and electric locomotives.

These types of locomotives have much in common, as their developments have paralleled each other closely, and no one has ever questioned that it has been entirely proper and satisfactory to fabricate all cab work by means of electric welding.

The smooth external appearance and streamlining that has characterized these types of large locomotives has been made possible for the most part by welded construction.

There has also been general acceptance of an all-welded cab underframe, and it is believed that, if there had been more adequate facilities for building such assemblies as these locomotives came into demand, there would be little use of the cast underframe today.

However, the cast type underframe has proved satisfactory for use with the diesel switcher, and it is quite unlikely that it would now be found economically worth while to attempt to fabricate underframes at a lesser cost than castings. Conversely, as larger and more powerful passenger and freight service locomotives are developed it is unlikely that it will be possible for a casting to compete with an all-welded underframe.

Carried on the welded and cast underframes we find diesel engines which are in themselves outstanding tributes to the welded method of fabrication. These engines are very complex weldments, the parts of which are assembled and welded to literal precision tolerances.

In general a diesel engine weldment consists of frame and bedplate units which, in the production process, are made up of other sub-assembled and welded units.

It is obvious that such weldments can be fabricated in quantity lots on a production basis which need be limited only by the manufacturing facilities available. Planned and repetitive sequences of welding minimize distortion, and stress relief annealing produces a totally stable structure for machining.

It might appear that maximum use of welding has been made on the diesel engine, but in giving credit where due, an equally noteworthy development has been made on the lowly electric mine locomotive.

This type of locomotive is now a completely all-welded assembly on which it has been possible to eliminate all machining operations other than drilling.

The major difficulty normally encountered in this type of locomotive is that of alignment of axles, and which in the welded construction has been overcome by the simple expedient of simultaneously flame-cutting the pedestal openings in pairs from a single template layout.

The assembly is characterized by an appearance of substance and ruggedness which is not so readily in evidence in other types of construction.

As has been previously stated, the primary objective of this paper has been to record current applications of fusion welding to locomotive construction for the purpose of indicating design and construction trends, and it is hoped that this brief review will not only encourage some, but will convince all, that there is place and need for this type of construction and that even more substantial developments in its applications are ahead of us.

Structural Welding*

By Van Rensselaer P. Saxe†

PROBABLY without realizing it to be a fact, the structural fabricating industry is on the brink of the most revolutionary change to which it has ever had to adjust itself, so being interested in the fabricator holding his present position, I am taking the liberty of pointing out some existing conditions affecting engineers and fabricators.

This change is being brought about by the gradual advance of structural welding from a position of minor importance even five years ago, to one of enough importance today to see fabricators advertising that they actually do welding, to the not too distant future when the fabricator will see his entire fabricated output as welded material.

There are a number of factors bringing about this change in the method of building fabricated structures, chief of which is probably the speed with which welded fabricated work can be assembled and erected, which results in great economies.

This change will not be as bad for the fabricator as many of them are inclined to feel at the present time, for this element of economy will be the means of producing a greater demand for fabricated steel and it will help fabricated steel to get to a closer approach to reinforced concrete costs which for so many years have been a thorn in the side of the fabricating shop. Further, this will be a change in fabricating methods which will not cause the fabricator to lose business as was the case when the competition of reinforced concrete caused the fabricator to lose thousands of tons of profitable fabricating, to say nothing of the low fabricating prices forced by competition with reinforced concrete.

By the use of structural steel methods of construction formerly patented, as, for instance, the System *M* light steel beam reinforcing member, it is possible today to design a light fabricated welded structure at a cost equal to the cost of bar reinforced structures, which method, if adopted by the fabricators, would soon put them back in full competition with their greatest competitor and as time and investigation go forward to the point that the shops equip themselves to secure the fullest economy for welding shop methods, there will be an unmixed blessing in the advent of welding.

The danger to the established fabricator lies in the fact that the fabricating of welded structures is so simple and requires so little capital investment, that anyone with a thousand dollars and a small line of credit can get into the fabricating game, for while such a person could not buy at the mills, he can purchase from local warehouse stock, pay higher prices for his material and through the economies resulting from welded fabrication operations, he can beat the costs of riveted fabrication as now done and sold by the larger shops.

Do not toss this statement aside as not being capable of fulfilment, but rather, if you know even a little about welding, study the matter to see how difficult it will be to complete with the fellow who starts out with the small capital investment, required to do welded work, who can order his steel cut to proper length or cut it with a burning torch, ship it directly to the job site, as can be done in most cases outside large cities, weld in place on the ground, the necessary clips and bearing seats to hold the steel in place when erected, then erect the steel, welding it in place after erection.

If you think for a minute this cannot be done practically, read Mr. Davis' account of field fabrication and erection of the Lincoln Building in the August issue of THE WELDING JOURNAL. It has been done, in my opinion, too many times for the best interest of the fabricator, and should make him think of what can be done in a well-organized shop to combat such situations.

Think of the greater economy resulting from use in the shop of resistance welding to assemble plates and beams so much used for spandril and lintel beams and actually today being used in one well-organized structural fabricating shop, think also of the greater speed and consequent welding economy that can be secured by use of shop automatic arc welding for assembly of plate girders and rigid frame roof structures, which are so much more economical than any of the hand-welding methods.

If the present established fabricator will think along these lines, he is going to keep his worst competitor from ever getting started; if he does not, then the fabricators are going to be up against the toughest problem they ever faced. The old problem of combating reinforced concrete was a baby by comparison to what this man-sized affair is going to be.

Personally, I want to see today's fabricator hold his present position, for it is through the complete organization he maintains that the owner and engineer get service for value paid, for I know from experience how difficult it is for the engineer to have an owner say, "Well, such and such a welding shop, properly equipped, and employing only qualified welders, has submitted a figure this much lower than so and so's structural shop, and why should I not give the job to him, if he has some engineer make the structural detail drawings for him, which you can correct or approve?"

Gentlemen, this is happening too often now, for it has happened to us, and the small welder makes more money than he dreamed of making, though he probably did not make as much as the overhead expense of his structural competitor.

The way to head off your competitor is to figure on what he could do, and then stop him by adopting the most modern methods. Don't try to scare off the customer by telling him all the dangers of welding, when you can't put your finger on any good evidence, as I have so often seen tried by fabricators opposed to welding, who then lost the job anyway, for it's hard work to separate an owner from his dollars when he has once seen a saving. If you doubt this, take a look at the welded ship industry today, compared to what it was ten years ago.

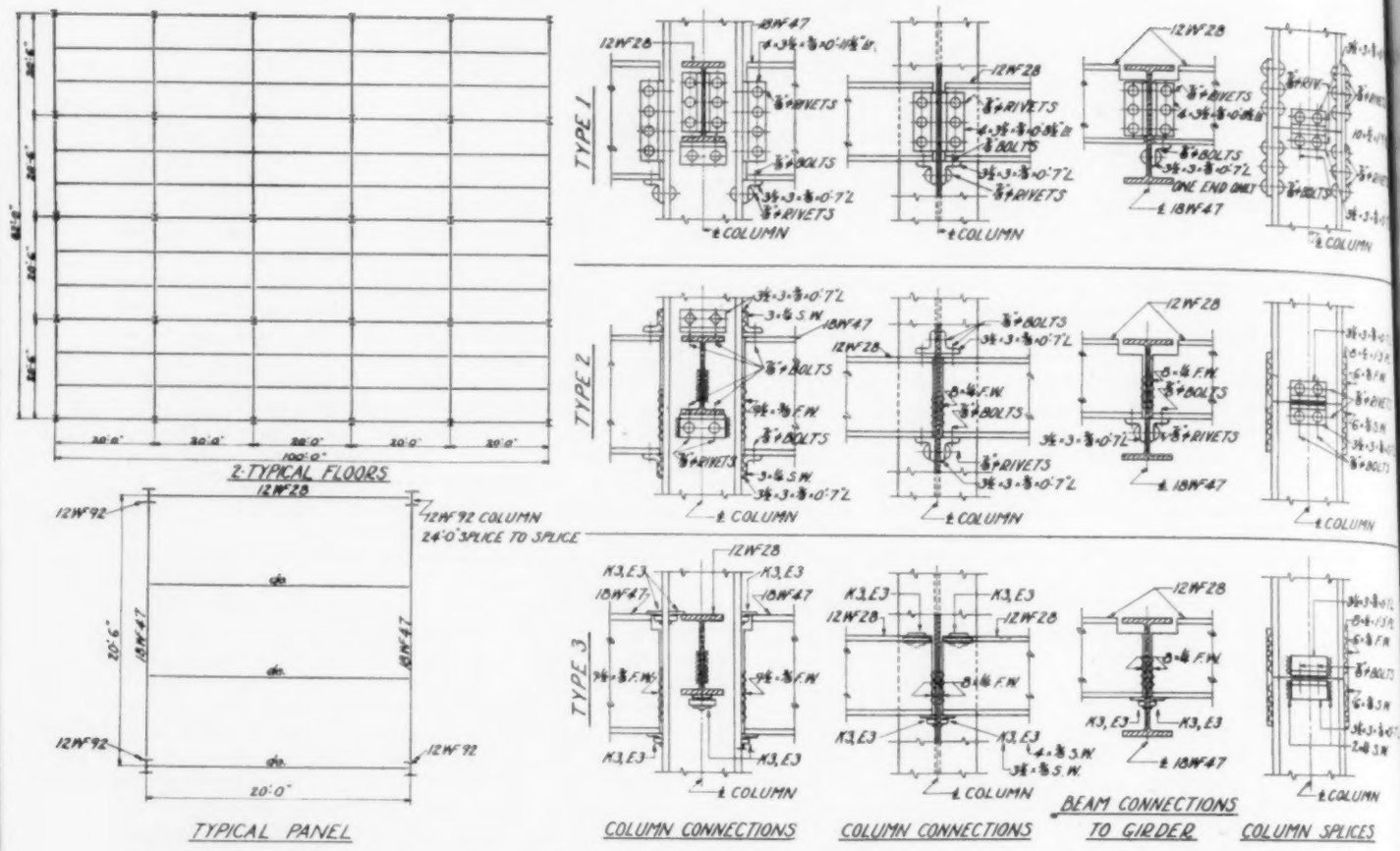
While structural welding has many admirable qualities to recommend its use, its fundamental quality, as I have said before, is its economy and the possibilities for further economy in material required when it is used.

* To be presented at the Annual Meeting, A. W. S., Philadelphia, Pa., Oct. 20 to 24, 1941.

† Consulting Engineer, Baltimore Md.

Summary of Costs Covering Similar Items of Work

Type 1—Riveted—193,411 lb.—costing $9232.41.
Type 2—Field Bolted and Welded—188,527 lb.—costing $8371.98.
Type 3—Erection Seats, All Welded—186,468 lb.—costing $7826.25.



In its primary form, the case for welding rests on the comparative cost of a rivet in place in the holes required to place it, as compared to the cost of an equal amount of weld value applied direct to the steel with no fabrication of holes to keep the weld in place.

To establish a comparison, I have developed the costs of three different methods for assembling, using two typical floors and a two-story column length of a theoretical multiple-story building, about which type of building there seems to be the most controversy as to whether or not a welded structure creates cost savings when compared to the usual forms of structural assembly.

The welded costs are based on design assembly similar to that shown in the 1938 Edition of the A. W. S. Welding Handbook on page 983 and Fig. (*b*) on page 984 with certain modifications such as including a top clip angle at the beam connections to columns to keep the sway out of the steel frame during erection.

This type of connection is economical and has been used in our office for years under all conditions of beam length and loading, though in recent years we have replaced the angle connections as illustrated by the last or Type 3 illustration showing the use of the patented erection seats, which we have found to be more economical, because of simplified shop fabrication requirements, and the saving made in erection time, due to the fact that a beam once put in place in the structure requires no further attention, such as temporary bolting before either riveting or field welding, as is the case with either the framed riveted structure or the field bolted welded structure used for the comparative costs.

It will be noted that the column size selected is one that can be punched, whereas if column sizes were such that they would have to be drilled as is often the case in the lower columns of a multiple-story building, the immediate effect on these figures would be to raise the costs of Type 1 and Type 2 but would not affect the costs of Type 3, for no punched or drilled holes are required in columns in which the erection seat is used.

These costs have been established with the help of a gentleman, owner of a medium-sized structural shop and represents an average condition for this type of shop not equipped for heavy work.

Such similar items as milling columns, shop detail drawings, actual erection costs, by which I mean getting the steel in place ready to rivet or weld, can be assumed to be the same with the exception noted before.

The actual field cost, work of attaching by rivet or weld the beam ends to girders or columns and column splices, has been included in the costs of the individual items.

While fair costs have been established, I do not, of course, expect shops to agree in detail, but even if this is not done, not much cost change can be developed by revamping of the figures.

One item should be mentioned in connection with this type of welded connection, namely whether or not beams should be ordered plus or minus $^3/_8$ in. or have milled ends.

From our experience in this type of work, and we have done considerable of it, we do not believe that milling the ends of beams justifies the small expense that might be saved in welding due to a beam cut slightly short under usual fabrication cutting.

Only once in our work has a fabricator elected to mill the ends of all beams, though we had one other case in

Type 1*—Full Riveted Construction

(Steel for two floors)

Beams Between Girders:					
Shopwork—					
80 12 W. F. B. 28 x 20 ft. 0 in.	44,800 lb.	P2	@ $1.50	$ 120.00	
320 angles 3 1/2 x 3 x 3/8 x 0 ft. 8 1/2 in.	1792	cut, layout, punch	0.15	48.00	
480 7/8 shop rivets	240		0.20	96.00	
Material	46,832		0.035	1639.12	
Fieldwork—					
160 field erection bolts in place			0.20	32.00	
288 7/8 field rivets in place			0.55	158.40	$2093.52
Beams Between Columns:					
Shopwork—					
50 12 W. F. B. 28 x 20 ft. 0 in.	28,000	P2	1.50	75.00	
200 angles 3 1/2 x 3 x 3/8 x 0 ft. 8 1/2 in.	1120	cut, layout, punch	0.15	30.00	
300 7/8 shop rivets	150		0.20	60.00	
Material	29,270		0.035	1024.45	
Fieldwork—					
200 field erection bolts in place			0.20	40.00	
180 7/8 field rivets in place			0.55	99.00	1328.45
Girders Between Columns:					
Shopwork—					
48 18 W. F. B. 47 x 20 ft. 0 in.	45,120	P2	1.50	72.00	
192 angles 4 x 3 1/2 x 3/8 x 0 ft. 11 1/2 in.	1674	cut, layout, punch	0.20	38.40	
80 angles 3 1/2 x 3 x 3/8 x 0 ft. 7 in.	368	cut, layout, punch	0.15	12.00	
160 7/8 shop rivets	80		0.20	32.00	
384 7/8 shop rivets	192		0.20	76.80	
Material	47,434		0.035	1660.19	
Fieldwork—					
192 field erection bolts in place			0.20	38.40	
768 7/8 rivets in place			0.55	422.40	2352.19
Columns for Two Floors:					
Shopwork—					
30 12 W. F. B. 92 x 24 ft. 0 in.	66,240	P3	3.00	90.00	
60 10 x 1/2 x 1 ft. 9 in. splice pls.	1785	cut, layout, punch	0.30	18.00	
120 angles 3 1/2 x 3 x 3/8 x 0 ft. 7 in.	552	cut, layout, punch	0.15	18.00	
196 angles 3 1/2 x 3 x 3/8 x 0 ft. 7 in.	902	cut, layout, punch	0.15	29.40	
480 7/8 shop rivets	240		0.20	96.00	
312 7/8 shop rivets	156		0.20	62.40	
Material	69,875		0.035	2445.63	
Fieldwork—					
240 7/8 field bolts			0.20	48.00	
480 7/8 field rivets			0.55	264.00	3071.43
Shop handling charge for material through layout, punch and riveting	193,411 lb.		@ .002	386.82	386.82
Total					$9232.41

* See sketch.

which some 36-in. girder beams were milled to assure a neat fit.

Even if milling is added to the figures as developed, it is a comparatively small extra cost added to the structure and still will not affect the final comparative savings to any material extent, as any one interested can develop by adding this cost.

How can a riveted connection ever hope to eventually compete against a welded connection, especially when columns have to be drilled, when the comparative costs show such a great difference on one simple layout? In the more involved connections such as those generally used for wind stress or rigid frame, the welded connection shows even greater proportional savings.

But the savings due to connections, except in the multiple-story building, are the smallest part of the savings that can be made, due to use of welding in such buildings as factories, airplane hangars, auditoriums and similar buildings where trusses or plate girders are generally used for the support of roofs.

Due to the fact that in truss and plate girder work there are no hole areas to be deducted from tension members, and that it is possible in compression members to use such combinations of shapes as angles and channels placed toe to toe to get maximum value of compression from all compression members, it is a certainty that any roof truss designed with structural T's for top and bottom chords, which eliminates the necessity for gusset plates, can be designed and built and erected in place with a saving of at least 20% under the cost of a similar riveted truss.

The shop fabrication work on either welded trusses or plate girders is considerably less than similar work on riveted material. As an illustration of one of the savings, no templates are required for hole punching, no fitting up and reaming holes for good rivets. In a well-organized shop equipped with a jig laid out for welded truss work, the difference in cost of shop assembly can be startling, as many shops working under a good welding set-up well know.

You may well wonder, with welding able to accomplish such savings, why it has been developing so slowly up to the time two years ago, when it began to show definite signs of reaching for the home stretch.

The answer to this is quite simple. Structural welding, like reinforced concrete, which went through its formative and experimental period, had to be developed by research and experimentation by the pioneers in its use, until other engineers became convinced that the work of the engineers who early started its use, showed it to be a reliable and safe method for assembly of structural steel.

This attitude was most pronounced on the part of

City Building Authorities, who appear never to have forgotten some of the early building disasters due to use of uncontrolled reinforced concrete, and consequently looked upon welding as a somewhat similar concoction, not knowing that the knowledge of welding developed from highly controlled methods used for industrial processes, long before it was ever even considered for use in structures, in which the highest elements of safety were required. Happily, this early attitude has changed, for the gradual and conservative use of structural welding has demonstrated to these men its reliability and the fact that methods used for its installation promote the highest degree of safety.

Unfortunately, too, until recently there has been no handbook obtainable, which gave engineers willing to use welding, information about welded connections in such a manner that they could easily and quickly determine the amounts of welds required for all of the different size beam connections, similar to the way this information is given in the steel company handbooks.

Without this type of information, designing of a welded structure involved much more detail calculations and drawing detail illustrations than is the case of a riveted design in which the details can be covered by reference to the handbook standard details.

However, with the handbooks now available, this hurdle has been crossed and engineers can now design the beam and girder type of building with the same degree of speed that they are accustomed to develop on riveted or reinforced concrete designs.

Many engineers still feel that welding is not safe, but this, as in the early stages of the development of reinforced concrete, is only because they have not had opportunity or taken time to find out how safe it really is. Today I know engineers who are most ardent exponents of reinforced concrete who, when it first came into use, thought it almost an act of criminal negligence to use it in a structure where human beings were housed. The present frame of mind toward welding will change, too, when they know more about it, from trying to learn what it will accomplish. This will be especially true when they run into more and more owners who demand the utmost economy in their work, or they have some fabricator familiar with welding offer an alternate welded design for one of their riveted designs, as happened recently to an engineer friend of mine. He did not like it, but he soon got around to learning something about welding.

During our present defense program the use of welding in structures we have designed has saved many tons of steel which could be devoted to other purposes. Under today's conditions of difficulty in getting steel shapes, fabricators are constantly coming back to us with substitute sections made up of some smaller depth section with plates welded to the flanges to make up an equivalent to the original deeper sections required.

We have some buildings that would be delayed for

Type 2*—Field Bolted and Welded Construction

(Steel for two floors)

Beams Between Girders:					
Shopwork—					
80 12 W. F. B. 28 x 20 ft. 0 in.	44,800 lb.	P1	@$1.00	$ 80.00	
Material	44,800		0.035	1568.00	
Fieldwork—					
320 7/8 field erection bolts in place			0.25*	80.00	
320 field weld (1/4 x 8)			0.60	192.00	$1920.00
Beams Between Columns:					
Shopwork—					
50 12 W. F. B. 28 x 20 ft. 0 in.	28,000	P2	1.50	75.00	
Material	28,000		0.035	980.00	
Fieldwork—					
200 7/8 field erection bolts in place			0.25	50.00	
200 field weld (1/4 x 8)			0.60	120.00	1225.00
Girders Between Columns:					
Shopwork—					
48 18 W. F. B. 47 x 20 ft. 0 in.	45,120	P3	2.00	96.00	
160 angles 3 1/2 x 3 x 3/8 x 0 ft. 7 in.	736	cut, layout, punch	0.15	24.00	
192 7/8 shop rivets	96		0.20	38.40	
Material	45,952		0.035	1608.32	
Fieldwork—					
384 7/8 field erection bolts in place			0.25	96.00	
192 field welds (3/8 x 9 1/2)			0.75	144.00	2006.72
Columns for Two Floors:					
Shopwork—					
30 12 W. F. B. 92 x 24 ft. 0 in.	66,240	P1	2.50	75.00	
60 8 x 1/2 x 1 ft 3 in. splice pls.	1020	cut	0.10	6.00	
120 angles 3 1/2 x 3 x 3/8 x 0 ft. 7 in.	552	cut, layout, punch	0.15	18.00	
120 7/8 shop rivets	60		0.20	24.00	
200 angles 3 1/2 x 3 x 3/8 x 0 ft. 7 in.	920	cut, layout, punch	0.15	30.00	
200 7/8 shop rivets	100		0.20	40.00	
192 angles 3 1/2 x 3 x 3/8 x 0 ft. 7 in.	883	cut, layout, punch	0.20	38.40	
384 welds (1/4 x 3)			0.25	96.00	
120 welds (3/8 x 6)			0.40	48.00	
Material	69,775		0.035	2442.12	
Fieldwork—					
120 splice plate welds (3/8 x 6)			0.50	60.00	
120 field bolts in splice			0.25	30.00	
120 field bolts in clips			0.25	30.00	2937.52
Shop handling charge for material through layout, punch and riveting	188,527 lb.		@ 0.0015		282.74
Total					$8371.98

* See sketch.

Type 3*—Full Welded Using Erection Seats

(Steel for two floors)

Beams Between Girders:					
Shopwork—					
80 12 W. F. B. 28 x 20 ft. 0 in.	44,800	no punching			
160 erection clips			@$0.15	$ 24.00	
160 erection clip shop welds (3/8 x 3 1/2) in place			0.25	40.00	
Material	44,800		0.035	1568.00	
Fieldwork—					
320 field welds (1/4 x 8)			0.60	192.00	$1824.00
Beams Between Columns:					
Shopwork—					
50 12 W F. B. 28 x 20 ft. 0 in.	28,000	no punching			
200 erection clips			0.15	30.00	
200 erection clip shop welds (3/8 x 3 1/2) in place			0.25	50.00	
Material	28,000		0.035	980.00	
Fieldwork—					
200 field welds (1/4 x 8)			0.60	120.00	1180.00
Girders Between Columns:					
Shopwork—					
48 18 W. F. B. 47 x 20 ft. 0 in.	45,120	blocked only		15.00	
192 erection clips			0.15	28.80	
192 erection clip shop welds (3/8 x 3 1/2) in place			0.25	48.00	
160 erection seats			0.13	20.80	
160 erection seat shop welds (3/8 x 4) in place			0.30	48.00	
Material	45,120		0.035	1579.20	
Fieldwork—					
192 field welds (3/8 x 9 1/2)			0.75	144.00	1883.80
Columns for Two Floors:					
Shopwork—					
30 12 W. F. B. 92 x 24 ft. 0 in.	66,240	no punching			
60 8 x 1/2 x 1 ft 3 in. splice pls.	1020	cut	0.10	6.00	
120 angles 3 1/2 x 3 x 3/8 x 0 ft. 7 in.	552	cut, layout, punch	0.15	18.00	
120 spl. pl. shop welds (3/8 x 6)			0.40	48.00	
120 spl. angles shop welds (1/4 x 4)			0.40	48.00	
392 erection seats			0.13	50.96	
392 erection seat shop welds (3/8 x 4) in place			0.30	117.60	
Material	67,812		0.035	2373.42	
Fieldwork—					
120 spl. pl. welds (3/8 x 6)			0.50	60.00	
120 7/8 bolts in splices			0.25	30.00	2751.98
Handling charge—layout and welding on yard skids	186,468 lb.		@ 0.001		186.47
Total					$7826.25

* See sketch.

months if this were not possible, and, as these fabricators explain, the extra expense of substituting sections in this manner is negligible, compared to the expense of not being able to get the work through their shops.

We have had fabricators build up out of plates sections that were required, though I do not understand where they got the plates, which are supposed to be most difficult to secure.

It has been estimated that if enough welding of structures were done to save only 5% of the steel used for this purpose, it would amount to a clear saving of over 80,000 tons of steel a year, which steel could be used for other purposes.

When we consider that in 1932 about 12,000 tons of welding rod were produced as against an actual production of nearly 100,000 tons for 1940, which was used in every possible form of steel assembly, does it not seem practical for an established fabricating industry to seriously consider going into this new field in a little more hearty manner than has been done to date, before some other industry who realizes its advantages, gets a good toe hold on this fabricator's reluctance to develop while the going is easy.

The use of welding, due to its greater speed in fabrication, will permit more work to go through an established shop than can now be done by the riveting process, and for this reason, if no other, it should establish higher profits for each year's work.

It is admitted that today there is a shortage of welding mechanics for structural work, because of the great demand and higher wages paid in the shipbuilding and other industries but don't forget that when this ship work slows down, there will be thousands of able men looking for work, and when the shops familiar with welding have this situation in hand, they are going to turn out welded work at costs so low no riveted structure can be within reaching distance.

Too many structural shops feel that welders are too highly paid. In defense of this high pay I would like to point out .hat I have observed many highly paid skilful welders who in one day would turn out work at a dollar value, which the poorer paid man made cost one dollar and a half.

Fabricators should realize that the savings due to welding are so considerable that it pays to employ the skilful worker, and even though his wage is high, his work will put the shop beyond the reach of competitors not similarly staffed. The ship-building industry found this out long ago; in time the fabricators will discover it.

Fortunately for the fabricators, in the past ten years not many have put in new equipment, so they are in a position now that too much present equipment value will not have to be written off with the advent of increased use of structural welding.

Today's averaging of investment for equipment should

be done by purchasing of new welding equipment. Get the best for shop purposes operated under central control methods. Study carefully the economical operating values of each type of welding equipment. Try to get the advice of shops already equipped for most economical welding methods, considering even automatic and resistance welding equipment which serve the same purpose as the multiple punch and bull riveter in the riveting shop. These have a most definite use in what will be the well-equipped fabricating shop of the future. The development of the rigid frame type of shop structure with its many benefits to the lighting effects and other outstanding qualities will require just this type of equipment.

These methods and these only are going to keep the fabricator in the structural fabricating business, for the day is not too far distant when all owners will demand the most economical structure; so when that day arrives, we engineers and fabricators should be ready for it.

In concluding, it has appeared to many that both the engineer and fabricator are in a dilemma because of this rapid advance in use of structural welding. A careful investigation of all the conditions involved in present and future situations due to the use of welding can, with proper foresight on the part of those affected by the method of fabrication, be turned into a tremendous advance in economy of structural fabrication.

This will eventually mean more business for both engineer and fabricator, which is anything but a dilemma.

Training Brazing Instructors for National Defense*

By Leo Edelson†

Reason

AFTER approximately seven years of experimenting with various types of joints for joining non-ferrous pipe in naval construction, the United States Navy Department selected as a standard the "Silbraz" insert type fitting. The final selection of this type of silver brazed joint was arrived at after many years of laboratory work, wherein new designs were submitted and tested, and as the result of a long period of field experiences which were carefully checked and evaluated. It must be appreciated that, with the acceptance of this type of fitting by the Navy Department, the use of screwed thread full weight pipe was, in a very short period of time, practically eliminated.

Under ordinary ship construction conditions, which were in effect previous to the national emergency period, a service and training organization had been set up by one of the valve and fitting vendors which proved satisfactory. However, with the inception of a two-ocean Navy and the subsequent tremendous expansion in all marine construction, it soon became apparent that this organization could not function efficiently and would be unable to expand rapidly enough to meet the present emergency. It was therefore decided that the next logical step would be the formation of so-called "Teacher Schools" for instructors, who could in turn extend their activities in teaching the great number of men who will undoubtedly be needed from now on, as the defense program expands. This project was carefully drawn up and submitted to the Navy Department, who enthusiastically lent their support and have contributed materially to the success of the project. It is the purpose of this paper, by a careful breakdown of this program, to be of material help and guidance to those manufacturers who may have a personnel or servicing problem in connection with their products wherever they fit in with Navy Department requirements.

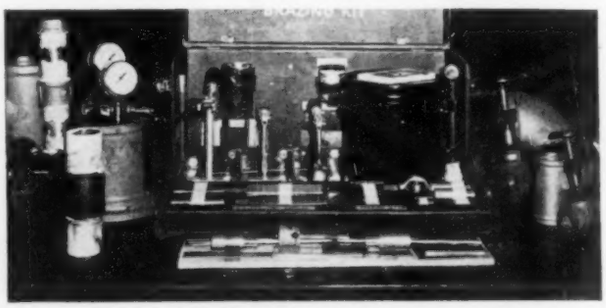


Fig. 2—Brazing Kit

Program Plan

This program was basically conceived to train at least one man from the copper shop and one man from the pipe shop of each naval constructing yard, or possibly more where the work load might be heavier. But it soon became apparent that this plan could be materially ex-

* To be presented at the Annual Meeting, A. W. S., Philadelphia, Pa., Oct. 20 to 24, 1941.

† Handy and Harman, New York, N. Y.

Fig. 1—Text-Books and Certificate

tended; and when the project started, it was found advisable to operate along the following lines:

1. One or more men from both the copper and pipe shops to be trained as teachers.
2. One man to be assigned from the Navy Department Ship Construction Office in the district, who in turn could lecture and advise inspectors already functioning and any new inspectors who might be called to duty.
3. One representative of the fitting manufacturers in the district who could bring himself up to date on the latest marine practices and also become thoroughly familiar with the School's requirements and either teach, where possible, or cooperate to the fullest extent with the local school.
4. Men of the gas and equipment manufacturers in the district who could also serve the same function.
5. Men of the silver brazing alloy manufacturers who could serve in the same capacity.
6. Superintendents or foremen from yards recently formed, with no previous experience in Navy Department piping requirements, to become familiar with all phases of Navy Department practices.

Fig. 3—Brazing Close to Bulkheads

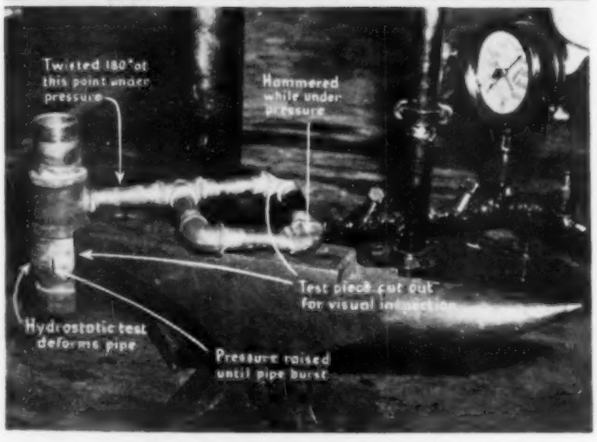

Twisted 180° at this point under pressure
Hammered while under pressure
Test piece cut out for visual inspection
Hydrostatic test deforms pipe
Pressure raised until pipe burst

Fig. 4—Completely Tested Assembly

It was decided that (with the cooperation of the Navy Department) the Walworth Company, the Air Reduction Sales Company and Handy and Harman would act as sponsors and operate one school at the Air Reduction Sales Company Laboratories in Jersey City. All yards east of the Mississippi, from Maine to Florida, the Gulf Coast and the Great Lakes districts, would participate in this school program. Upon completion of the sessions in the East, the school was reopened in San Francisco for men on the West Coast from San Diego to Seattle. At the request of the Navy Department, representatives attended from each repair ship attached to the Pacific Fleet and also men from the Destroyer Repair Base at San Diego, as well as a teacher from the Navy Department Welding School. It is the intention of the Navy Department to include this instruction as an integral part of a course to be extended to all Fleet personnel who take care of maintenance.

Fig. 5—Brazing Copper-Nickel Tubing

The types of schools that are now in the process of opening vary to some degree and in some cases depend entirely on the individual requirements. It was found, that under the National Defense Educational Fund, moneys were available for the program. The necessity for trained help could be reported by a yard to the local school administrator, who in turn cleared the project through the State administrator, who presented the project to the National Defense Educational Fund, Bureau of Commerce, who would then allocate the necessary funds for the program.

In actual operation, some Navy Yards have found it desirable to institute the school through their regular Apprentice or Trainee School and in some cases both the Navy Yards and the private yards have found it desirable to open the school on their own property, utilizing

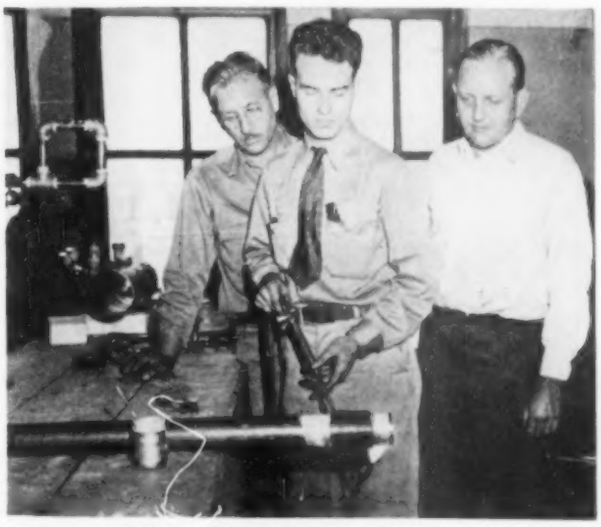


Fig. 6—Brazing Bulkhead Fitting

Fig. 7—Refrigeration Assembly

their own school and shop facilities, while in other cases it has been found preferable to open the classes in the local trade schools.

The program embraced:

1. Training and qualification of mechanics at present in the employ of the yards.
2. Training of so-called apprentices or trainees at present in the employ of the yards.
3. After discussing the project further with a number of unions, it was found practical and desirable to suggest to the plumbers, steamfitters and coppersmiths that they also attend these schools to prepare themselves, so that when ship construction in their district expands sufficiently to require their type of help, they will be available.

If it is remembered that the basic conception of this school was not to train mechanics, but rather to train men to act as instructors, it can readily be seen that much extra time had to be allocated, so that the explanation of all points could be made and clearly recognized by each teacher-student. The time of the school, as outlined, started on Monday morning at 9 o'clock and ran to Friday afternoon at 5 o'clock. The enthusiasm displayed was of such a nature than in many cases the men gladly contributed to overtime class work.

Operation

The school program was basically laid out so that Monday could be given over entirely to theory. At the beginning of the class, each man was presented with a reference book (Fig. 1 *A*) containing literature contributed by the three sponsors and the Navy Department, as his personal property, for intensive study while he attended the school. Notebooks were also supplied and frequent use of written notes was not only required, but, I might say, almost mandatory. Where possible a blackboard was used and the men directed to take notes; the thought being that when a man takes time to put information down on paper, he not only has a source of ready reference for himself, but undoubtedly retains more of the information in his memory.

Each morning at least a half hour was given over to a review of the previous day's activities and the men were encouraged to take notes at this time. As new projects were started during the day, the men were given sufficient time to continue making their notes.

Tuesday, Wednesday and Thursday were given over to the practical application of brazing, which will be elaborated upon further in this paper.

On Friday, qualification tests were given, together with a written examination. The written test reviewed points which had been brought up verbally or had been put on the blackboard for notebook purposes.

Upon completion of the course and the acceptance by the instructor of the students as competent, each man was presented with a certificate (Fig. 1 *B*) and was also given a written review of the course for future guidance (Fig. 1 *C*).

For the benefit of students who attended these courses, and as a possible guide to others who may have use for the material, the following is a detailed report of the activities of the daily classes.

Monday

Issuing literature and notebooks, signing in and introducing each man in turn to the rest of the class. Pairing up of men to act as teams—in most cases a mechanic and a non-mechanic, so that each could contribute to the other where possible.

Morning Session.—(*a*) Discussion of gas cylinders—their construction, safe handling, etc.

(*b*) Construction, design, safe handling of regulators, torches, tips and hose.

(*c*) Discussion of heat characteristics and heat flow.

(*d*) Discussion of the design of fittings.

Afternoon Session.—(*a*) Our company developed a brazing kit which has been widely used (Fig. 2). This kit, along with replacements, descriptive litera-

Fig. 8—High Pressure Fittings

ture and a carefully prepared instruction booklet (Fig. 1 *D*) giving directions for the proper presentation of the demonstration, was displayed to the men. The demonstration explains the fundamentals of proper practice, proper materials, design, etc., and very graphically, by actual eye training, brings out the highlights of the art of silver brazing. This demonstration, which ordinarily should take about a half hour, was extended in most cases to two hours, so that a thorough knowledge of how to run this show was imparted to the teacher-student. Our company has contributed one of these kits, together with the necessary literature and replacements, to all schools that have been started and will also offer the same service to any schools that may be opened in the future.

(*b*) On completion of the demonstration, a thorough discussion on the subject of fluxes and brazing alloys was given.

(*c*) The balance of the afternoon was given over to the proper methods of cutting pipe, preparing joints by suitable cleaning and proper fluxing practices. Assemblies were made up for the next day's work, as shown in Fig. 3. The questions of tolerances, rounds, square cuts, scribing, support of joint members while heating, etc., were then taken up and explained at this session.

It is interesting to note that throughout the school session, when statements were made by the teachers, great care was taken to see that the students would have to make their own specimens to prove these points and in all cases would have to destroy their own specimens to prove, to their own satisfaction, that all statements made could be corroborated. Testing equipment used includes hydrostatic test and hammer (Fig. 4).

Fig. 11—Jigs Assure Proper Tolerances

Tuesday

Morning Session.—(*a*) The first specimen made up (Fig. 3) pointed out to the men the proper application and proper torch manipulation so that they could make joints in all positions and in restricted places, and attempted to simulate shipboard construction as far as possible. The wood background simulated a bulkhead and the men were shown the safe application of heat as it pertains to both the ship and their own physical safety. The assemblies completed were severely tested to build

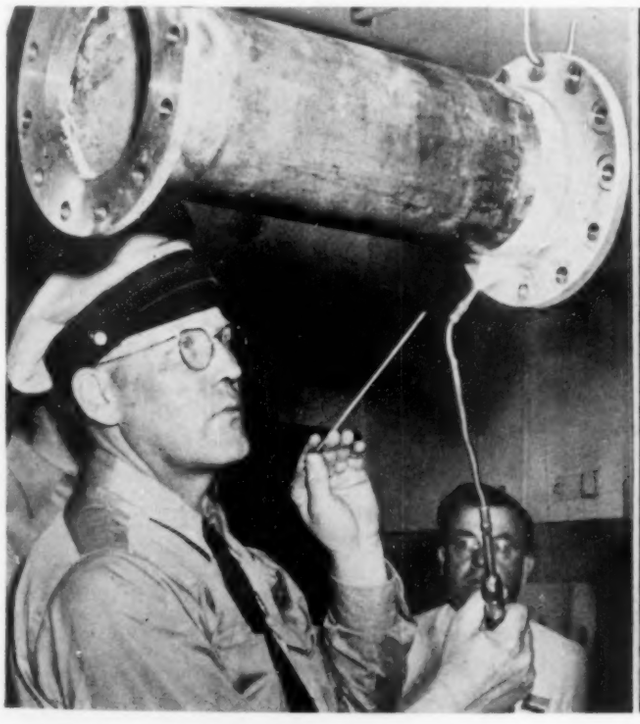


Fig. 9—Brazing Flange Overhead

Fig. 10—Brazing Flange Vertically

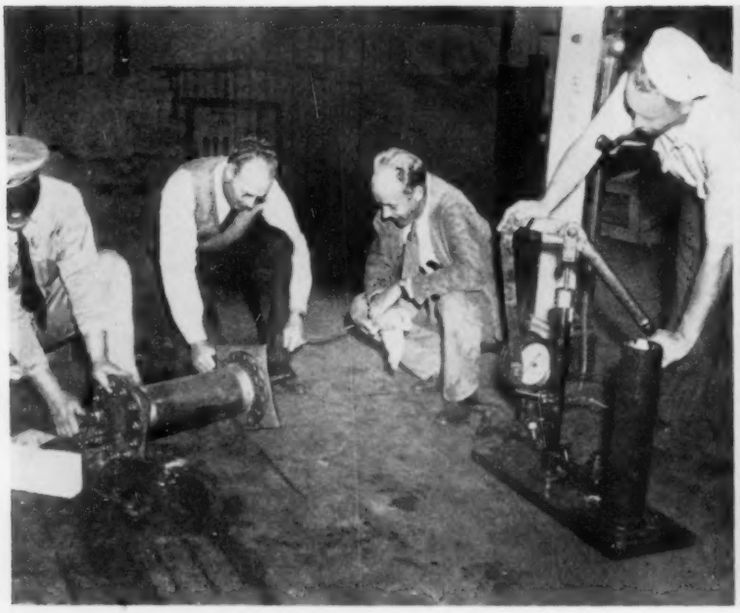


Fig. 12—Hydrostatic Testing

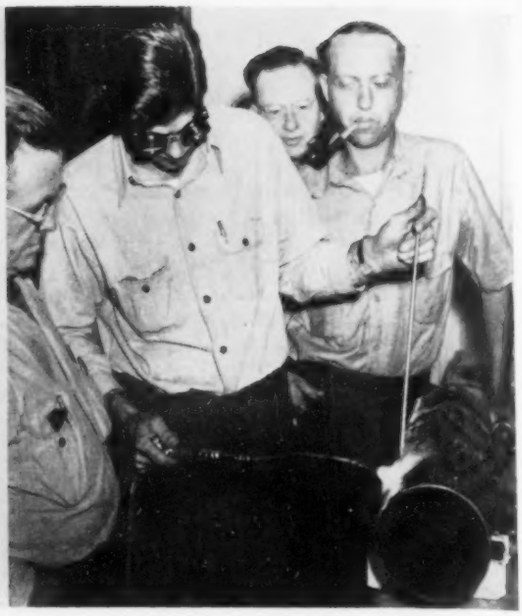


Fig. 13—Brazing Longitudinal Seam

up in the men confidence in their own workmanship and to prove that proper preparation of the joint and proper heating would insure the absolute in good joint construction.

(*b*) The specimens were first filled with water and 125-lb. fittings were brought up to 1500 lb. and carefully examined for joint porosity (Fig. 4). While at these pressures, the joints were hammered and deformed and were twisted through an arc of at least 180 degrees. Pressures were then increased so that failures occurred at the fiber stress of the pipe and in all cases the pipe split in a longitudinal direction in the 2-in. copper tubing. Of all the students who attended these courses, to the best of my knowledge, there were only two who produced incomplete joints which had not been thoroughly heated and these, after being properly heated, were retested and passed.

(*c*) On completion of the physical testing, the men were directed to cut their specimens (Fig. 4) so that they could get an inside picture of the joint. The students were encouraged to save their specimens, which were later forwarded to them to act as guides for both themselves and their students. As pointed out previously, all men were encouraged to work in groups of two and while one man was heating the assembly, the other man would watch and note mistakes. When he in turn did the work, his partner would have a chance to make similar criticism.

Afternoon Session.—(*a*) As the men completed and tested their work they were requested to make up an assembly consisting of a 2-in. tee and copper-nickel tubing (Fig. 5). Inasmuch as this material has different heating characteristics, these specimens were valuable in pointing out proper heating procedures as they pertain to copper-nickel. This tee assembly gave the three positions for brazing vertically upward, horizontal and vertically down ward.

(*b*) When about 50% of the men completed one specimen, the next step was explained to the entire group. This was important, because it afforded an opportunity to familiarize all the men with the next subject at the same time and encourage them to take notes. In all cases the "Do's and Don't's," peculiarities of each type of joint and proper procedures, were carefully outlined and in this way an attempt was made to give a thorough grasp of each problem to all the men present.

(*c*) Deck and bulkhead fittings were prepared and heated, one man doing a vertically upward joint, his partner doing a horizontal joint (Fig. 6). The specimen was then cut and hammered.

(*d*) Union specimens were made up, both assembled and unassembled, and procedure explained.

(*e*) Refrigeration assembly (Fig. 7).

(*f*) High pressure fittings (Fig. 8).

Wednesday

Six-inch flanges, copper to brass, were assembled and brazed as follows. Half of one flange joint was brazed by one man in a horizontal overhead position (Fig. 9) and the other half by his partner. Each man also did half a flange in the vertical position (Fig. 10). The proper procedure for tacking flanges to pipe in overhead positions, where assemblies would be taken down after fitting and brazed in the shop, was also explained. Note in Fig. 11 the jig used for achieving proper tolerances and roundness. Six-inch assemblies of composition flanges and copper-nickel pipe were made up in the same way. All assemblies were subjected to hydrostatic test (Fig.

Fig. 14—Brazing Bosses

12) and flanges were cut off so that pipe could be reused, and where requested were presented to the men for display purposes.

Thursday

As part of this school project, a course of instruction in the fabrication of copper pipe was given and the proper use of a suitable brazing material was thoroughly explained and demonstrated to the class. Then coppersmiths only were trained in this method (Fig. 13). The proper application for the brazing of bosses in all positions was demonstrated and all men present were requested to make this type of joint (Fig. 14). The application of a newly developed oxyacetylene torch was demonstrated to the group (Fig. 15). Qualification specimens adhering to Navy requirements were made up and thoroughly explained (Figs. 16 and 17).

Friday

All qualification specimens and tests were completed and each man took his written examination.

Procedure for Starting Schools

As a guide to those men who will start schools of their own, the following points should be highlighted:

1. *Starting the School.*—Where the need for new men and the training of old men is apparent, schools may be started in the existing school system of some yards under their present set-up.

2. *Request to Local Authority.*—Request should be made to the proper local technical school authority to incorporate these classes as part of the training program. The schools may be started either on the Navy Yard property or in a local school. In all cases, funds to cover the teachers' salaries, rent and insurance of the premises, necessary equipment and materials are provided by the National Defense Educational Fund. There are some states that have special arrangements, but they are so varied that I shall not attempt to cover them in this paper.

3. *Time.*—These courses may be given, as in some yards today, during the working hours and the men are paid while they learn. In other cases the courses are given as evening classes where the men attend on their own time and at no cost to them. The classes are planned for ten to twelve men for a period of three hours per evening, 3 to 5 times a week, total time for course being 40 to 50 hours.

4. *Class Layout.*—Classes should be provided with a blackboard, chairs to accommodate the students, as well as one make-up table containing at least four 6-in. vises and

Fig. 15—Demonstrating Annealing Tip

Fig. 16—Preparing Qualification Specimens

Fig. 17—Testing Qualification Specimens

1 brazing section with about 4 brazing stations. Suitable jigs should be supplied for overhead position for 6-in. pipe and also a qualification test rack should be provided. A testing section is necessary, containing hydrostatic pumps and an anvil, with suitable water facilities for filling and draining the specimens. Small tools and materials, such as hammers, hack saws with blade replacements, pliers, files, emery paper or sand cloth, flux brushes and flux, as well as waste rags, should be provided. The testing section should contain sufficient gaskets, bolts and wrenches. In the brazing section 5 brazing outfits are required, which should include 2 stage regulators and 15 ft. of $^{3}/_{16}$-in. oxyacetylene hose per station, along with a properly developed type of flexible extension torch, as pictured in Fig. 16. This type of torch is mandatory for the school, inasmuch as this is the only practical type of torch used in ship construction. The proper number of 6, 8 and 10 tips, spark lighters, tank and torch wrenches are of course desirable. All students are expected to supply and have on hand proper eye protection which should consist of either spectacles or goggles with the proper shade of lens —as covered by Federal Specification—for this operation. It has been the writer's experience that most brazing operators select too dark a shade of lens which contrib-

utes to eye fatigue and in no way assists in protecting their eyes from the deleterious rays generated by the oxyacetylene torch. Men are also requested to supply their own gloves.

Lockers and washrooms should be made available to the men wherever possible.

Materials

Due to the request for detailed information on the materials required for this course, a classified list is given below.

Group 1

10 2 x 3/4-in. Tees*
10 2 x 3/4-in. Caps*
10 3/4-in. Tees*
30 3/4-in. 90-degree Ells
10† pieces 2 x 6-in. IPS Yellow or Red Brass Nipple[3] one end threaded
10 pieces 2 x 6-in. IPS Type B Copper Tube
50 pieces 3/4 x 4-in. IPS Type B Tubing

NOTE: All pipe, while specified as pieces, is only so specified to show the size of the unit and should be purchased in continuous lengths so that students can obtain practice in properly cutting their pipe.

Group 2

5 2-in. Deck Sleeves*
1 piece 2-in. x 4-ft. Type B Copper Tubing

NOTE: These members are started on one end and as parts are completed deck sleeves are cut off and the next sleeve is then fastened on the long length of pipe.

Group 3

10 2 x 2 x 2-in. Tees*
60 inches Copper-Nickel Type B 2-in. Tubing

NOTE: This material should take care of a number of classes, inasmuch as the ends may be cut close to the fittings and the ends reused.

Group 4

5 1 1/2-in. Unions*
30 inches 1 1/2-in. Type B Copper Tubing

NOTE: This material is cut in half and unions are brazed on and cut back until the pipe is used up.

Group 5

10 2-in. Couplings*
10 2-in. Caps* Tapped 1/4-in. IPS
120 inches 2-in. Copper-Nickel Tubing

NOTE: This material is for the Navy Qualification Test and these specimens should be given to the men for their personal use, properly stamped by the inspector to signify that they have passed the test.

Group 6

20 6-in. 125-lb. Brass Flanges*
36 inches 6-in. Type B Copper Tubing
36 inches 6-in. Copper-Nickel Tubing

NOTE: As flange tests are completed, flanges should be cut off and pipe reused for next specimen.

Group 7

10 3/8-in. Refrigeration Valves
20 3/8-in. Tees*
24 inches 3/8 in. Type B Copper Tubing
20 3/8-in. 90-Degree Ells*

NOTE: This is the refrigeration set-up.

Group 8

5 1-in. 3000-lb. Fittings*
4 feet 1-in. IPS Copper Pipe
5 pounds Flux[1] (1/2-lb. jars)
3 pounds 0.050 x 1/8-in. Brazing Alloy[2] No. 3 U. S. Navy Spec. 47513C
2 pounds 3/32 in. Brazing Alloy[3] No. 4 U. S. Navy Spec. 47513C

This is the high-pressure set-up.

For the original construction of jigs used in Fig. 3, four brazing stations will require four 2-in. cast-iron flanges threaded, four 2-in. nipples 15 in. long and four 2-in. cast-iron tees.

Summary

It is the writer's belief that the instructor should have an assistant, or select one of the students to work under his supervision, to take care of the assembly bench and to oversee all testing. This will permit the instructor to give all his attention to the training of the men in the proper heating methods and also give him additional time for planning the work.

Wherever possible, rigid rules of conduct in classes should be set up and carefully adhered to, although it has been the writer's experience that these courses are so interesting to the students that the foregoing suggestion may possibly be superfluous.

Inasmuch as the course is based on a definite continuity, it is of the utmost importance to see that men who are absent more than one evening be dropped from the course. However, if the absences are unavoidable the student may be offered the privilege of taking the course over in another class. It is the writer's opinion that if the men indulge in too frequent absences the continuity of the course is interrupted and the main advantage of the course is lost to both the student and the school. It will also be found that the burden placed upon the instructor in bringing the absentee's work up-to-date is far too great.

Conclusion

It has been calculated that within the next two years approximately 5000 to 7000 new men will be required in this field, and possibly more. A course of this kind can also do considerable good in up-grading and training men who are now employed in the yards, but who have had limited experience in this type of construction.

We believe that the above outline will prove of great assistance to the men who have received this course of training in our school and we intend to continue to cooperate with these men and with the program as a whole, to see that competent operators are available throughout the United States and in the Fleet to install good piping properly, safely and rapidly, wherever the need arises.

Acknowledgment

The author desires to express his appreciation to the members of the Walworth Company, the Air Reduction Sales Company and Handy and Harman for their assistance and courtesy in allowing the publication of these data.

* Silbraz.
† This member is later cut approximately 1 in. from the threaded end and reused as a boss later in the course.
[1] Handy Flux.
[2] Sil-Fos.
[3] Easy-Flo.

The Radiographic Examination of Heavy Plate*

By O. R. Carpenter†

IN recent years an extensive increase in the number of pressure vessels fabricated by fusion welding of heavy plate has shown a need for a more efficient technique for the radiographic examination of these welds. By heavy plate we mean to consider that which is 2 in. thick and more, it being in this thickness range that the phenomenon of secondary radiation begins to seriously hamper the effectiveness of the radiographic test. This radiation so lowers sensitivity that, regardless of the many refinements of technique devised for its control, frequently evidence is found to indicate that the radiograph of a weld in a heavy plate has failed to disclose the presence of a fine crack or discontinuity. It has been the writer's experience, for example, that upon re-examination of test welds, cracks are sometimes found by means of a magnetic test, which extend an appreciable depth into the seam. These cracks could not be found in the radiographs of the areas, although the 2% penetrameters required by the Boiler Code were clearly seen. This radiographic failure may be due to any or all of the following: the alignment of the crack was not with the primary radiation; the faces of the crack were not widely enough separated to allow a sufficient X-ray absorption differential to produce a visible image on the film; the secondary radiation is in too great a proportion to the primary radiation, causing the loss of image detail on the film. In light plate radiographs, where a sensitivity considerably under 1% of the plate thickness is easily obtained, no evidence such as that described above is experienced, for in this thickness of plate negatives are obtained which have the clearness of a pictorial photograph. Figure 1 is the reproduction of a radiograph approximately one-fifth original size of a 1-in.-thick plate. This test plate was made up of a group of plates, the defective portion being of $^1/_4$ in. thickness, and for this radiograph was placed on the tube side. It may be observed that the defect is visible with excellent detail and contrast; any layman would have satisfaction in his own interpretation of this radiograph without the aid of a so-called radiographic expert. As the plate thickness is increased to 2 in., however, by the addition of a 1-in.-thick plate to the group radiographed for Fig. 1, the detail displayed by the thinner plate thickness disappears, leaving the image of only the major portion of the defects shown by Fig. 1. The reproduction of the radiograph of this test plate, now 2 in. thick, is shown in Fig. 2 at about $^1/_5$ actual size. The 2% penetrameter required by the Code is clearly seen, yet we know a large percentage of the defects present are not to be seen on the negative.

A number of years ago a study was made by the writer to determine at what thickness provisions should be made to eliminate the secondary radiation from the radiograph. For this work a series of tests was made on plates ranging from 2 to 3 in. thick. These plates were radiographed using a varied series of techniques, some

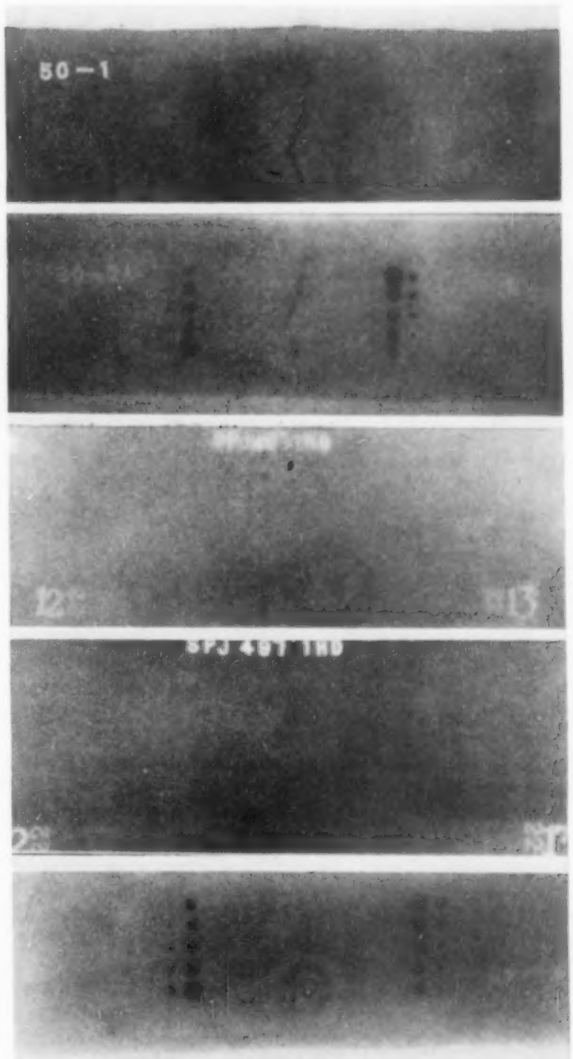


Fig. 1—Radiograph of 1-In. Plate Having Prepared Defects Included in Weld

Fig. 2—Plate with Prepared Defects Radiographed at 2 In. Thickness

Fig. 3—Weld 2.25 In. Thick Radiographed Without Grid. Note Small Slag Inclusion Over 12

Fig. 4—Same Weld as Fig. 4 Radiographed with Grid. Note Additional Slag and Detail

Fig. 6—Prepared Cracked Plate Illustrating Loss of the Detail After It Has Been Built Up to 4-In. Thickness

* To be presented at the Annual Meeting, A. W. S., Philadelphia, Pa., Oct. 20 to 24, 1941.

† Babcock & Wilcox Co., Barberton, Ohio.

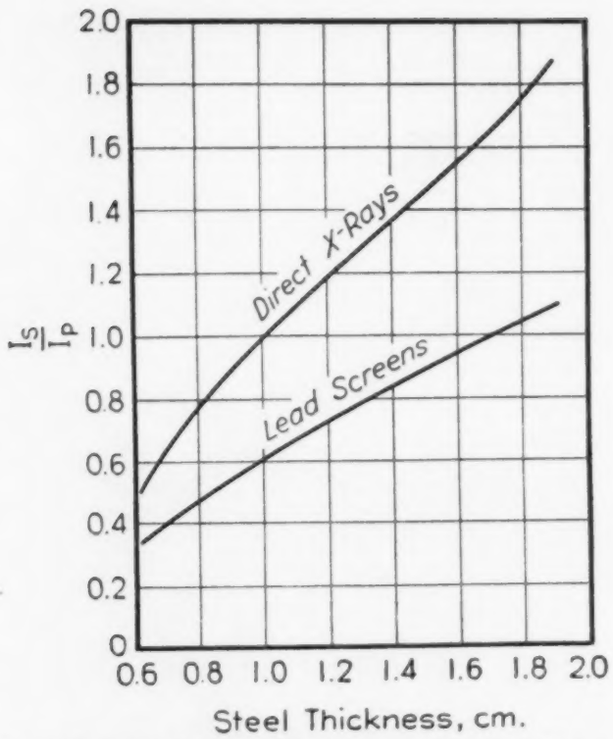


Fig. 5—Proportion of Secondary Radiation as a Function of Thickness of Steel at 200-Kv. Constant Potential. (After Seemann)

of which included the use of the Bucky grid. In one series of approximately 15 ft. of weld, slag inclusions and porosity approximately 13 in. in length were shown on the radiographs of a $2^1/_4$-in.-thick weld taken with the Bucky grid which could not be seen on radiographs using regular technique. Figure 3 is a typical film taken without a grid, while Fig. 4 is a duplicate film using the Bucky grid. The additional detail is obvious, yet the former film will pass the requirements for code radiographic examination. Based upon these tests, a ruling was made in the shop requiring the use of a grid on all thicknesses 2 in. and over.

The effectiveness of the grid and other methods for the elimination of secondary radiation has been found to be excellent in the lower thickness ranges of heavy plate. As the plate thickness increases, however, the ratio of the secondary to primary radiation increases. Dr. Seemann has studied this effect[1] for radiographic purposes and has shown (Fig. 5) that for 200-kv. X-rays and for 2-cm. plate the ratio is more than three times that found for $^1/_2$-cm. plate. It is doubtful if, as the plate thickness increases and as the X-ray wave length and absorption decrease, this ratio remains the same. However, it is well to consider that although the scatter becomes less effective as the wave length shortens, at the same time increases in plate thicknesses will correspondingly increase the number of scattering points. We might, therefore, assume that in spite of the lower absorption characteristics and consequently less scattering of the harder rays, the ratio of the scattered radiation to primary radiation remains constant for proportional decreases in X-ray wave length.

In general our experience with gamma rays indicates the problem of scattering for this radiation to be much less than for X-rays. Would this experience remain valid were this radiation to be used on plate thicknesses in the same proportion to its wave length that we have become accustomed to in the use of X-rays? In other words, proper X-ray technique for heavy plate perhaps should be to use a wave length whose scattering coefficient is in correct proportion to the plate thickness.

In Fig. 6, for example, a reproduction of a radiograph is shown in which the test plate of Fig. 1 has been built up to 4 in. thick. The Bucky grid, 400-kv. X-rays, 5 milliamp., Eastman screens and a 3-hr. exposure were the technique used. It will be noted that all but the major defects shown in Fig. 1 have disappeared from the radiograph. The main crack shown represents approximately 8% of the plate thickness in depth and 4% in width. The fine crack, just visible, is somewhat less in percentage. The detail of the latter is entirely gone and could easily be assumed to have no major significance. The telltale holes drilled on either side of the cracks are 2% and 4% in depth, respectively, and range from 1 to 12% of the plate thickness in diameter. The cracked plate was located at the tube side during exposure of the film.

The above-described test seems to indicate that possibly when working at 400 kv. the secondary radiation is in such high proportion to the primary radiation as to fall into a very inefficient range of X-ray technique, or that the Bucky grid is not very efficient at this voltage, over long exposures, and for large quantities of secondary radiation. Whether or not secondary radiation is the entire cause of the loss in detail illustrated by the above is open to question. However, it is definite that some of the cause is found there and that the significant fact remains, namely, that in heavy plates, even with definite provision for the elimination of secondary radiation, the detail of the film falls to a very low grade in comparison with the results possible in the lighter plate ranges. Similar sensitivity is needed in the examination of heavy plate in order to be sure of the disclosure of fine defects. In this paper we are to describe some steps taken to improve the quality of heavy plate radiographs and to point out that rather than prescribe a constant radiographic sensitivity, as now done in Code requirements, this factor should become less for increased plate thicknesses.

Means for Control of Secondary Radiation

When X-rays pass through any material the beam suffers certain modifications; part of it is scattered much as visible light is scattered by fog, part is transformed into radiation of a different character and part is absorbed in the material. This secondary radiation is actinic and, therefore, if allowed to reach the film produces a fogged effect which reduces the contrast and detail. The best negative, therefore, in radiography is one

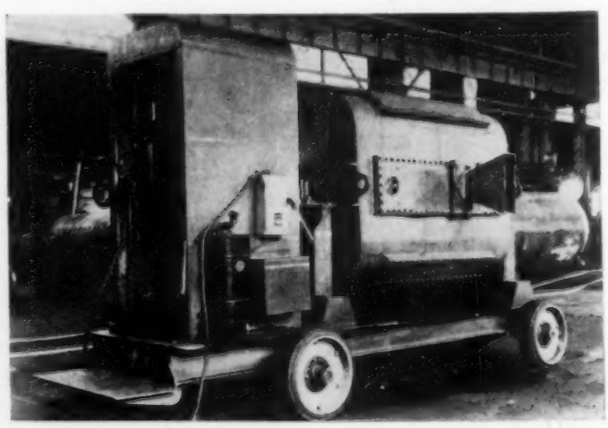


Fig. 7—400-Kv. X-ray Equipment

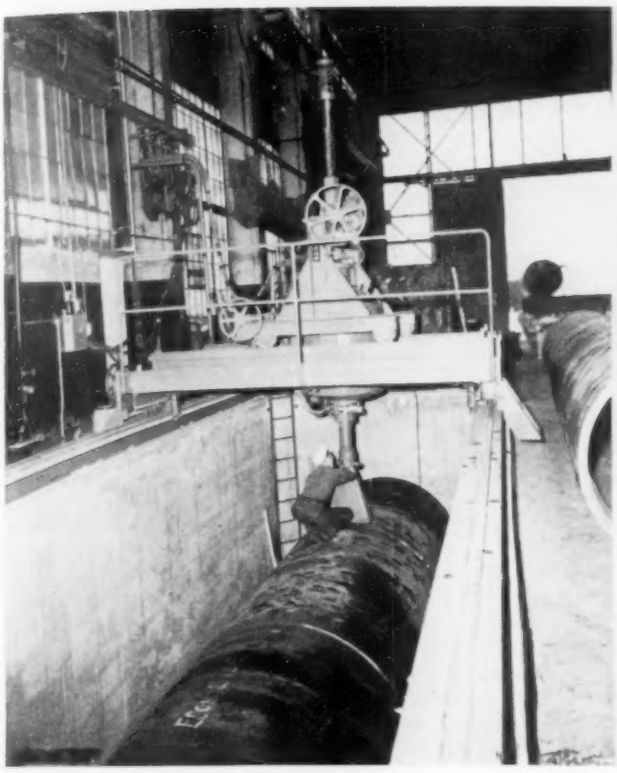


Fig. 8—View of Radiation Pit for 1000-Kv. Installation

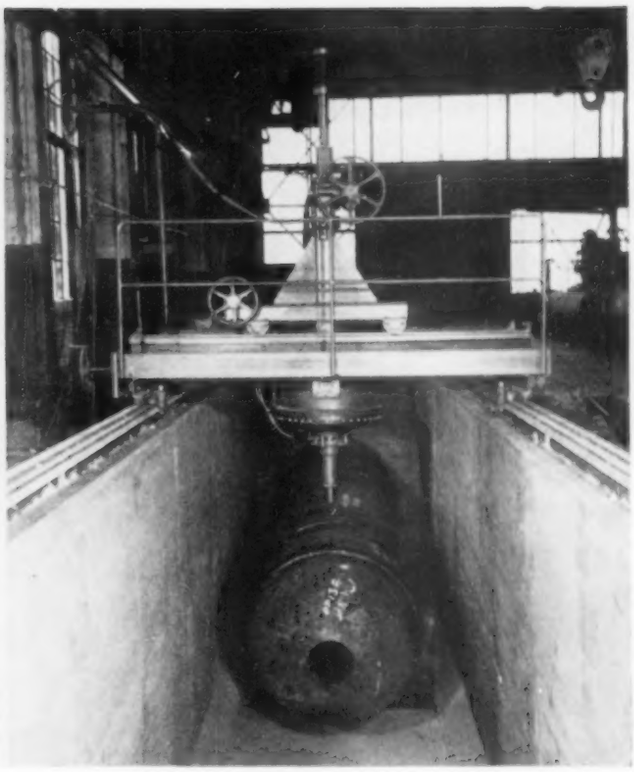


Fig. 9—View of Radiation Pit from Opposite End Shown in Fig. 8. The Lead Cone and Shielding Have Been Removed from the Anode Extension Chamber

which has been exposed to a minimum quantity of scattered or secondary radiation and a maximum quantity of direct radiation.

A number of means have been devised to control secondary, all of which consist of filters which are inserted between the object and the film and whose purpose is to absorb the longer wave length and softer secondary and yet allow the direct radiation to reach the film. In some work a sheet of pure lead or a combination of lead and other metals, such as copper, tin, etc., is found to be an effective filter. These have been found by the author to be of value for radiographs of thickness ranges from $1^1/_2$ to 2 in. A series of lead grids placed in a position so that their faces are parallel to the direct radiation, permitting its passage, yet absorbing angular secondary radiation is found more efficient than filters in thickness ranges greater than 2 in.

When the grid is left stationary over the film, shadows of grid lines are projected to the film, where they offer interference to interpretation. The Potter-Bucky grid is one designed to oscillate over the face of the film and expose the entire film to an equal density, thereby eliminating the grid shadows. An additional refinement is a combination of both the filter and the grid. It has been found that a thin sheet of lead placed between the grid and the film does much to improve the quality by absorbing the soft secondary from the face of the grid.

The more numerous of these refinements introduced, the greater becomes the cost of radiographic examination. In the examination of welded pressure vessels, where the object is to obtain a flaw-free and serviceable product, the added cost would not bear great consideration were one assured not only of practical results but of an ability to radiograph a welded drum in some reasonable period of time. Until recently the most powerful industrial X-ray equipment available on the market was one which operated at a peak voltage of 400,000 volts (see Fig. 7). This machine will penetrate up to 5 in. of steel, but requires approximately $3^1/_2$ hr. per exposure, using, of course, the Bucky grid for secondary elimination. The results obtained are open to the question of sensitivity, described above, and at the same time the long time required for the complete radiographic examination of a drum often produced pressure from production men for some means for radiographic inspection which would not require as much or more time than the welding of the drum itself.

The Use of Gamma Rays

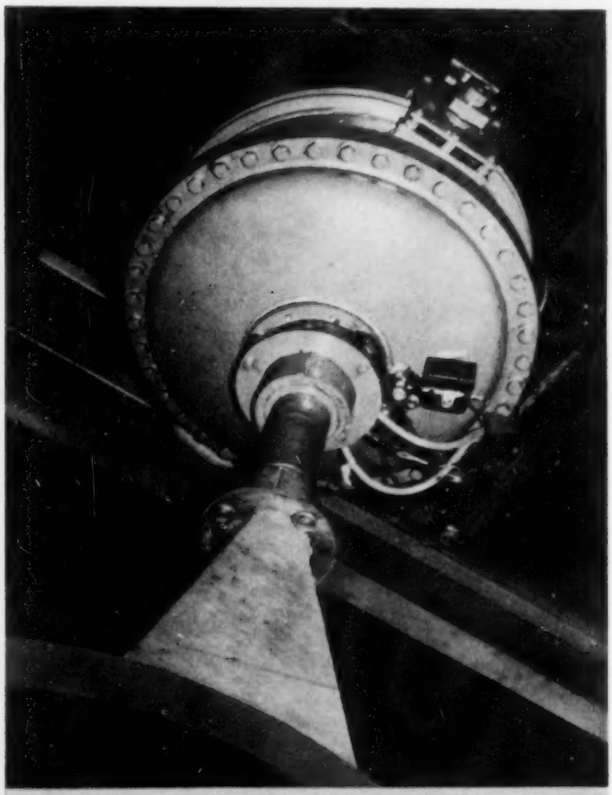
A typical heavy seam on a boiler drum requiring radiographic examination would be one approximately 72 in. in diameter and $4^1/_2$ to $5^1/_2$ in. thick. The use of 400-kv. X-rays will require for a 5-in.-thick drum approximately 100 hr. total exposure time. A 200-mg. capsule of radium will give effective films in about 70 hr., a 500-mg. capsule in approximately 24 hr. In addition to this advantage, the absorption coefficient for longer wave-length radiation is much higher than the shorter waves, so that the high angular secondary of gamma radiation is easily absorbed in the metal and leaves the emergent scattered gamma rays in a cone of very narrow angular distribution. These rays should, therefore, assist the image-forming power of the radiation rather than destroy it, as with longer wave-length X-rays. These advantages of gamma rays made it appear to be more efficient for plate thicknesses 4 in. or more than 400-kv. X-rays. A suitable technique was therefore worked out and radium used in some trial work. A typical film and defect is shown in Fig. 17. It was found that a 2% sensitivity gage could be clearly shown in heavy plate work but that the contrast factor was considerably below that of similar X-ray films. In

other words, doubt as to the ability to show clearly the entire weld condition continued to exist.

The approximate effective wave length of gamma rays is said to be that of 0.007 A.U.; that of 400-kv. X-rays approximately 0.05 A.U. For the range of plate thickness of 4 to 5 in., where radiographs by both of these sources of radiation were not as effective as desired, a poor balance in the plate thickness, wave length and secondary relationship might be assumed to be the cause. A step in the right direction would, therefore, be to use a wave length which, for heavy plate, would give a secondary to primary ratio somewhere near that existing for $^1/_2$ to 1-in. plate. Higher voltage X-rays, somewhere between 0.05 and 0.007 A.U., would be the answer to this assumption.

Early in 1939 the author began to follow this line of thought by an investigation of the radiographic possibilities of 1000-kv. X-ray equipment then being developed by the General Electric Company and others and being installed in a few hospitals for medical work. Some industrial work was then also in progress at the G. E. Schenectady Works on castings. Two types of machines were under consideration, one of which was the Van de Graaf electrostatic generator. This equipment would operate at constant potential and at 1 to 2 milliamp., giving a very efficient means of X-ray production. The G. E. equipment consisted of a low-frequency resonance transformer with a coaxially mounted multi-section X-ray tube, all contained in a steel tank and using a compressed gas for insulation. In both types of equipment, because the tubes were kept under vacuum by a complicated vacuum system, and in the former mechanical machine the many moving parts made practical application in a boiler shop look doubtful. However, in November 1939, on a therapy machine built for an Eastern hospital, the G. E. X-Ray Corp. kindly cooperated with the writer in the examination of a $5^1/_4$-in. test plate. These films were made using 1000 kvp. at 3 milliamp. A 48-in. film distance was used with non-screen film and lead screens. The exposure required for this test was 8 minutes, as compared to 24 hr. with 500 mg. of radium, or $3^1/_2$ hr. with 400 kv. X-rays at 5 milliamp. and the Bucky grid. This early work showed 1000-kv. X-rays to be in many ways similar to gamma rays. Calcium tungstate screens were found to be of no value. The best technique used at that time consisted of a 0.015-in. front lead screen and a 0.005-in. back screen. "No screen" films with their higher contrast were found superior to regular film. No trouble was experienced in showing on the film a penetrameter step, with a $^3/_{16}$-in. drilled hole, of less than 2%. The contrast available on these films was not as good as 400-kv. work on the same plate, but was considered better than the results obtained with gamma rays. The principal advantage was thought to be found in exposure time.

Fig. 10—View from Under Transformer Head at Anode of Tube



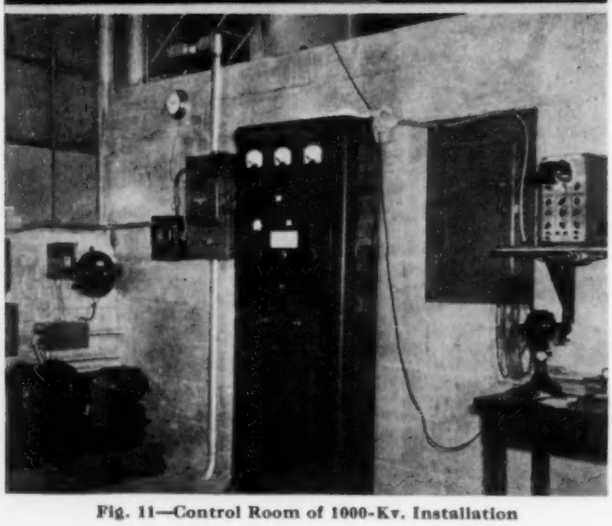


Fig. 11—Control Room of 1000-Kv. Installation

No further work was done in attempting to apply 1000-kv. X-rays to pressure vessel welds until the General Electric Co. announced the development of a million-volt machine considerably less complicated than the original and having a multi-section tube with a permanent vacuum. This gave tremendous possibilities as to portability and adaptability of the equipment to industrial work. Such a machine was built and installed at the Barberton Works of the Babcock & Wilcox Co. and placed in operation on production welds in July of this year. Below we will give a brief description of this equipment and point out the advantages derived therefrom over former methods for the radiographic examination of heavy plates.

Description of 1000-Kvp. Industrial Unit

For convenience in handling of drums and the positioning of the machine for individual radiographs, a pit 64 x 15 x 10 ft. was dug along one wall of a drum shop. The pit was considered best adaptable from the standpoint of X-ray protection and at the same time allow the use of present handling equipment for large drums (see Figs. 8 and 9) weighing up to 80 tons. The machine itself was mounted on a carriage which may be run over the length of the pit. The head was mounted on rails and trunnions, permitting its movement across the pit as well as its angulation to the face of the drum. Figure 10 is a view from under the machine, illustrating the latitude in positioning possibilities. The control room was installed in a separate and adjoining building at floor level, the entrance to which is through a con-

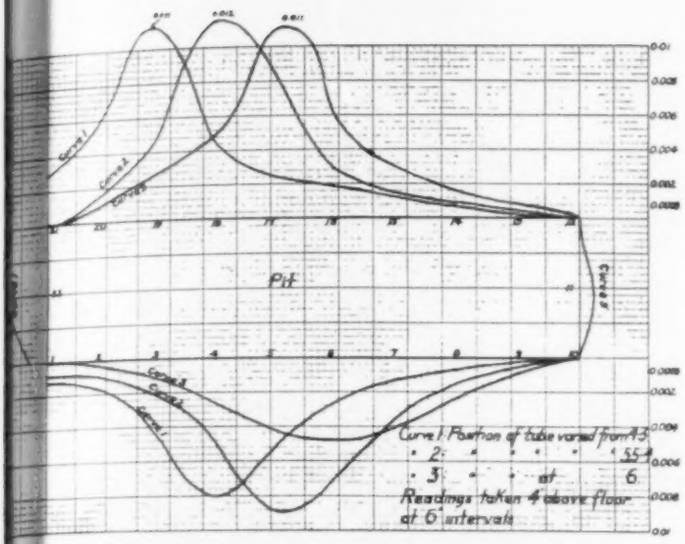


Fig. 12—Radiation Around Pit with 2-In. Lead Protection at Anode. Three Inches of Lead Reduces Readings to Below Tolerance Dose

crete maze having 18-in. walls, thereby shielding the operator with 36 in. of concrete. Figure 11 is a view inside the control room showing the control panel, the motor generator set and other accessories. Complete electrical details of the equipment are beyond the scope of this paper,[2] but for a better understanding of the compactness and possibilities of the machine a brief description will be included.

The head of the unit consists of a low-frequency resonance transformer with a multi-section X-ray tube coaxially mounted within the transformer, both of which are contained in a grounded steel tank, which contains compressed Freon gas for insulation purposes. The X-rays are generated by the bombardment of a grounded target situated at the end of the tube outside the tank proper. Power is supplied to the transformer from a 180-cycle synchronous motor generator, which power supply matches the natural period of oscillation of the transformer as well as makes the machine independent of line variations such as are usually present on most shop power supplies. The power is applied to the transformer primary by means of control of the output of the motor generator set. The filament current is controlled by means of a variable inductance in the filament circuit, the power to which is supplied from the top turns of the transformer. Since the cathode end of the tube is at high potential, the adjustment of the filament inductance is accomplished by means of a reversible motor-activated glass-insulating shaft connected to the filament inductance. The operation is very simple once the desired tube current is set, since the raising of the transformer primary voltage raises the filament current tap at the same rate as the transformer secondary. Only minor tube current adjustments need be made in normal operation.

X-ray Protection

Much consideration was given to the care required in the protection of personnel in and about a machine of this power when installed within a shop where other work was in progress. A pit below the floor level appeared to be the most practical solution from the standpoint of protection. Scattered radiation from the drum and other surroundings would at all times be below ground level. Therefore, the only radiation which would need to be absorbed would be the angular reflected radiation coming from the face of the target. The radiation at the smallest angular distribution from tube axis is absorbed by the transformer windings; that directly reflected back along the tube axis by a lead shield placed over the opposite end of the transformer case. There remains only the radiation over a small angle from the horizontal to be taken care of by lead shielding. The use of lead as a shield offered some surprise in the quantity required. Figure 12 is a plot of readings taken about the pit giving "r" per minutes obtained when 2 in. of lead were used around the anode. The valuable effect of distance may be observed here. When a third inch of lead was added to the anode protection, no point was found around the pit where a tolerance dose of 10^{-5} roentgens per minute was exceeded. No person is allowed in the pit during the operation of the machine. Warning lights automatically come on at the edge of the pit indicating that no one should enter it during an exposure. A ray-proof room at one end and in the pit has been built to provide space for a man whose job it is to position films for exposures. He remains in this room during all exposures and is in touch with the operator by signal light and telephone.

Technique with 1000-Kv. Equipment

Little in the way of past experience was available for reference in respect to the desired technique of this machine. Most of the available data were those obtained by General Electric Co. at their Schenectady Works and this was on castings, a problem different in sensitivity requirements from that of fusion welds. Other work, such as described above, had been done by Dr. Charlton in his laboratory at Schenectady. However, some basic facts were available for a start. It was, of course, known that the radiation would be near that of gamma rays in wave length and that the technique with respect to screens and films should be similar. Some conception of the exposure time required was available to the author from his work with Dr. Charlton done on test plates of $1^1/_4$, $5^3/_8$ and 8 in. thick. However, no information was known on the amount of secondary in 1000-kv. radiation nor what provisions, if any, need be made for its control.

The first work attempted was the radiographic examination of a $4^1/_2$-in.-thick circumferential seam on a large pressure vessel. The films and cassette used were similar to those employed in gamma ray work and consisted of a pack of lead screens and films. Two Eastman "no screen" films were placed between 0.015-in. lead screens with the films separated by a 0.005-in.-thick lead screen. Exposures were made at 1000 kv. and 1 milliamp. in a time of 6 minutes. The results obtained were found to be similar to gamma rays, somewhat inferior if anything. The markers, such as penetrameters, lead numbers and the general film appearance gave one the impression that considerable secondary radiation was present.

To investigate just what effect the amount of scatter present might be having on the film detail, a set of films was exposed using the Bucky grid. Double "no screen" films and lead screens were used, it having been found that all detail was lost when regular film and salt screens were tried. No attempt to reproduce the film without the grid was made, since the little detail and contrast present on the original film would have been entirely lost in the reproduction. In Fig. 13, however, we have reproduced the original Bucky grid film. Only a faint indication of the presence of the defect shown on the

right of this film could be observed on the film without the grid. The exposure required was found to be $2^1/_2$ times that without the grid. The resulting improvement of detail indicated that some provision needed to be made for the control of secondary radiation from 1000-kv. X-rays and that at this voltage the radiation was considerably different from gamma rays in its characteristics. The use of the Bucky grid, however, was one of the requirements of technique for heavy plate using 400-kv. X-ray, which it was hoped the 1000-kv. machine would eliminate. The appearance of the film obtained with the grid gave the impression that the filtration obtained was different in nature from 400-kv. work. Filtration of the primary beam at the anode was tried using up to $^1/_4$ in. of lead. This did not seem to improve the results measurably, although it was felt that a $^1/_8$-in. lead filter did offer some improvement in film detail. A stationary grid of French manufacture was then tried in place of the movable grid. Figure 14 is the reproduction of a stationary grid film showing a cracked weld in a $4^1/_2$-in. plate. It may be observed that the sharpness of detail is good but poorer than the Bucky grid film. This crack was located approximately 1 in. from the inside surface of the weld and was about $^1/_2$ in. deep. The grid lines make the interpretation of such films difficult and such defects as porosity are extremely hard to observe due to confusion with the grid lines. Further experimental work was next done with heavy lead filters at the film itself. Lead sheets, each 0.020 in. thick, were added to the face of the film cassette, loaded with double "no screen" film and lead screens, one at a time, and exposures made of a small defect in a 4-in.-thick plate until the total thickness of the filter reached 0.140 in. It was found that up to 0.090 in. of lead filter a steady increase in detail and contrast could be observed. Beyond this thickness little change could be noted. The addition of pure tin over the lead screens in the cassette made some additional improvement. The use of gold foil in place of lead screens made no further improvement, but did, however, increase the speed of the exposure by approximately 30%. In this respect it has been observed that the increase in speed due to gold foil screens with gamma rays is only of the order of 10%. Figure 15 is the reproduction of a radiograph of $4^1/_2$-in.-thick plate using a 0.090-in. lead filter with tin. Excellent detail can be observed.

To give some indication of the sensitivity available with 1000-kv. X-rays and lead filters, as described above, a film was exposed through a $4^1/_2$-in. plate using standard single thickness penetrameters for a series of thicknesses down to 2 in. Figure 16 shows a reproduction of this film. On the original the smallest hole in the 2-in. gage is visible. This hole has a diameter of approximately $^5/_{64}$ in., which is equal to slightly less than 2% of the plate thickness. The outline of the 2-in. gage is clearly seen and indicates that variations in thickness of less than 1% of the plate thickness may be shown. This method for sensitivity investigation is realized not to be entirely accurate, but it does give some indication of the possibilities and the superior contrast available. We plan, as more time becomes available, to make a more complete study of this factor.

A comparison of Fig. 15 with Fig. 17 will show to some extent the superior contrast of the 1000-kv. X-ray film to that of the latter taken with gamma rays. Close observation of the former will show the presence, clearly defined, of a line of porosity spots. The gamma ray film shows the slag clearly, but such fine detail as seen in the X-ray is not obtainable. Figure 18 is a reproduction of a film of a plate $2^1/_2$ in. thick, which is included to illustrate the possibilities at this thinner plate thickness. The detail of the cracks shown is quite equal to any lower voltage work.

Figure 19 is an exposure curve worked out for 950 kv. and a 36-in. film distance.

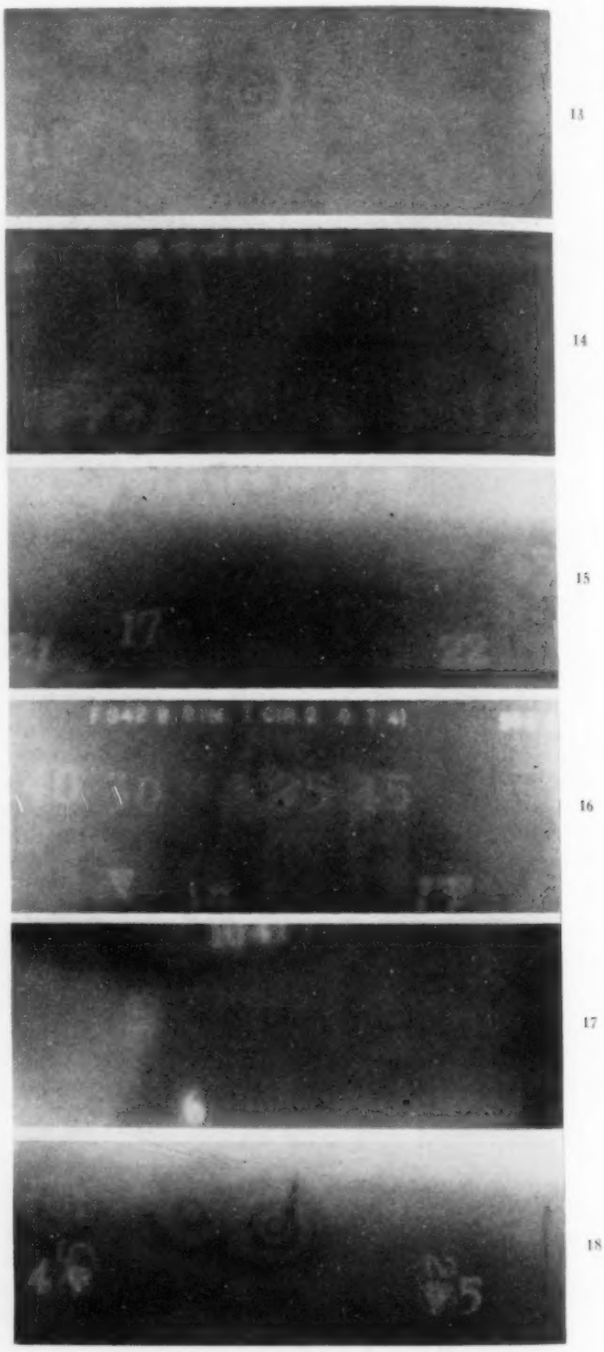


Fig. 13—Radiograph of $4^1/_2$-In.-Thick Weld Using Bucky Grid, 1000 Kv. and 1 Milliamp.

Fig. 14—Cracked Weld in $4^1/_2$-In. Plate Using Stationary Grid (950 Kv. and 1.5 Milliamp.)

Fig. 15—Slag Inclusion in $4^1/_2$-In. Plate. Technique: 950 Kv., 1.5 Milliamp. 0.090-In. Lead Filter Plus 0.010-In. Tin Filter

Fig. 16—Radiograph of $4^1/_2$-In.-Thick Plate Showing Group of Penetrameters. The 2-In. Gage May Be Seen

Fig. 17—Gamma Ray Film of 4-In.-Thick Weld

Fig. 18—$2^1/_2$-In.-Thick Plate, Cracked, Radiographed at 950 Kv., 1 Milliamp.

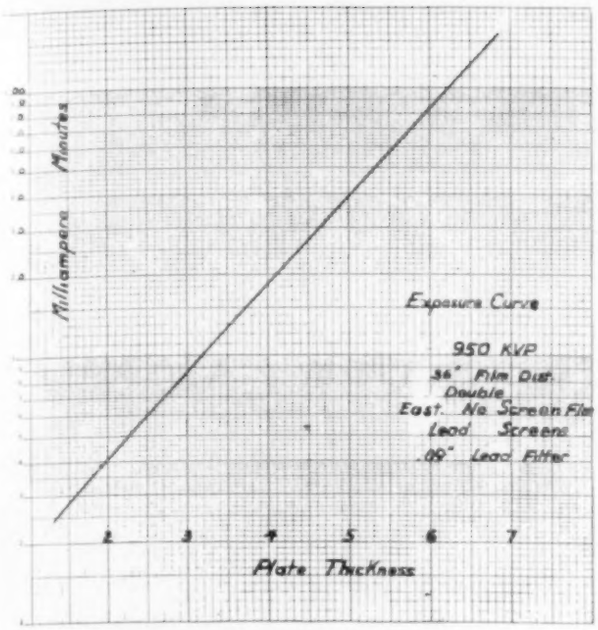


Fig. 19—Exposure Curve for 950-Kv. X-ray

Discussion

In the use of 1000-kv. X-rays many new experiences in radiographic examination have been found in the short time of the author's experience. Unquestionably the results possible on heavy plates are far superior to any heretofore obtained. Fine cracks show in exceedingly sharp detail.

The radiation is considerably different from gamma rays, and our experience indicates that some filtration is necessary at the film. Without any attempt to remove and control this radiation, the results are much on the order of a radiograph of a $1^3/_4$-in. plate taken at 250 kv. without filtration. Lead screens and "no screen" films have proved to be superior. The Eastman Kodak Co. has recently kindly sent us some experimental films for trial, which are of the type of the "no screen" film but are finer grained and slower. These are found to be superior to regular "no screen" film and since at 1000 kv. the time of exposure of 4 to 6-in. plate is not a serious factor, these experiments indicate that much will later develop to improve results with this machine through a more adaptable film.

An important advantage resulting from the availability of 1000-kv. X-rays is found in the elimination of the necessity of overreaching the technique range of lower voltage equipment. It is recognized that good X-ray technique is to use neither too short exposures at excessively high voltages nor too long an exposure at a voltage which will just allow penetration of the weld. The radiographic examination of a 5-in. plate with 400-kv. X-rays, which requires 3 hr. or better exposure time, falls into this latter classification. We now have available a wide range of X-ray equipment operating at peak voltages of from 200 to 1000 kv. To avoid overreaching the penetration ranges of this equipment and in recognizing that each of these machines has a valuable field of application, the following working range is believed to be necessary for good technique:

Equipment, Kvp.	Range of Thickness
200–220	Up to $1^1/_2$ in. (30 sec. min. exposure)
300	1 to $2^1/_2$ in. (use grid from 2 to $2^1/_2$ in.)
400	2 to $3^1/_2$ in. (use grid)
1000	3 to 7 in. (lead filters)

The above distribution of plate thickness with respect to machine voltage makes unnecessary excessively long exposures. With the exception of the very thick range listed with the 1000-kv. equipment, no exposure time will exceed 15 minutes. The 400-kvp. machine for the range of thickness given has been found to give somewhat better results than the 1000-kvp. machine does in this range. Perhaps the jump between 400 and 1000 kvp. is too great and better results would be obtained if the equipment could be operated somewhere between these limits. The writer, however, has made radiographs at 900 kvp. and could observe little or no difference between that and 1000 kvp.

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Jigs and Fixtures. Spot-Welding Jigs Speed Up Aircraft

(*Continued on page 727*)

Design of the World's Largest Welded Flat Car*

By H. Malcolm Priest†

THE operating needs of the Carnegie-Illinois Steel Corporation demanded a car suitable for transporting large ingot molds and other heavy products. As a basis for the design of such a car, the following requirements were established:

1. Loading Platform to be 18 feet 0 inches long and 9 feet 8 inches wide.
2. Height of Platform (when loaded) to be 2 feet 6 inches above top of rail.
3. Load to be 500,000 lb. distributed uniformly over the platform.
4. Car to meet all interchange regulations of the Association of American Railroads.

Having been designed in accordance with the last item, the car can be shipped over any railroad, provided that railroad meets the A.A.R. clearance diagram and its bridges have the necessary strength.

Preliminary calculations showed that the weight of the car would be somewhat more than 300,000 lb., making a total rail load of over 800,000 lb. This weight necessitated the use of twelve axles with 7 × 14 inch journals, each axle having a rated capacity of 70,000 lb. The general dimensions of the car, as finally developed from these basic specifications, are shown in Fig. 1.

The main body is of the depressed center type and is supported at each end on a car structure mounted on two six-wheel trucks. Welding was used throughout the main body and to some extent in the end supporting structures. In fact, it will be clear from the later discussion that welding provided the only feasible method of fabrication of this car.

It may be of interest to review several features of the design for they had a direct bearing upon some of the welding problems. As might well be imagined, the process of arriving at the final design was one of trial in which each step pointed to the next. The width limitation of the A.A.R. unrestricted clearance diagram had an important influence. When a working stress of 16,000 lb. per sq. in. was used, it was found impossible to pack the required number of beams between the limits of the diagram. This clearly called for a higher working stress and the use of a high-tensile steel. Another compelling reason for the use of a high-tensile steel was that of keeping the weight of the completed car within the capacity of the axles.

Figure 2 shows the final sizes of beams adopted for the platform portion of the car, where the stresses are a maximum. It will be evident how little margin of clearance there was. The bottom flanges of the outside beams projected beyond the limits of the diagram and required special consideration. A heavier section was selected, the lower outside flanges removed and a rein-

* To be presented at the Annual Meeting, A. W. S., Philadelphia, Pa., Oct. 20 to 24, 1941.

† Engineer, Railroad Research Bureau, U. S. Steel Corp. Subsidiaries, Pittsburgh.

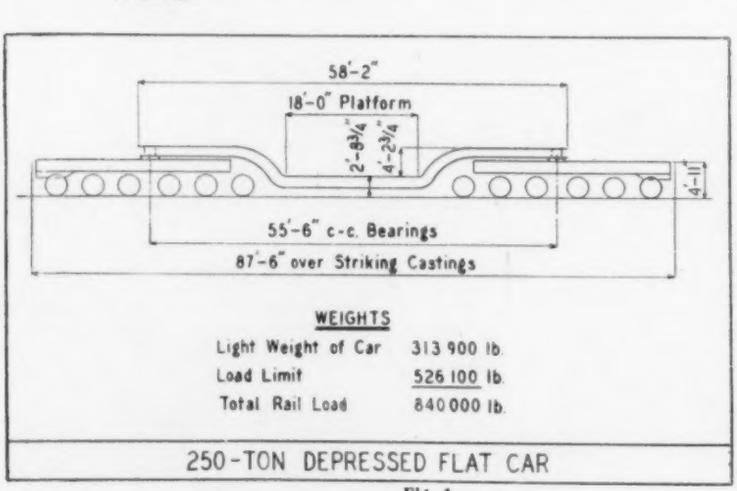
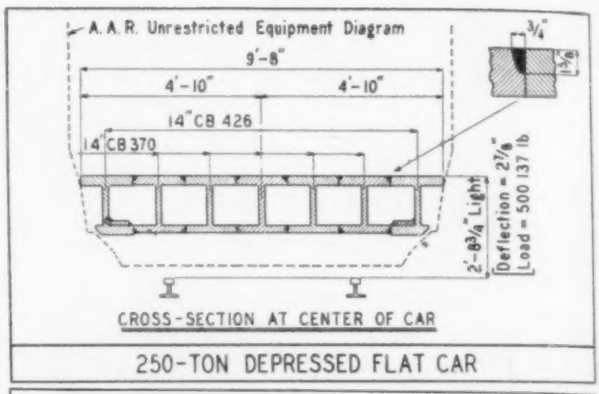


Fig. 1

Fig. 2



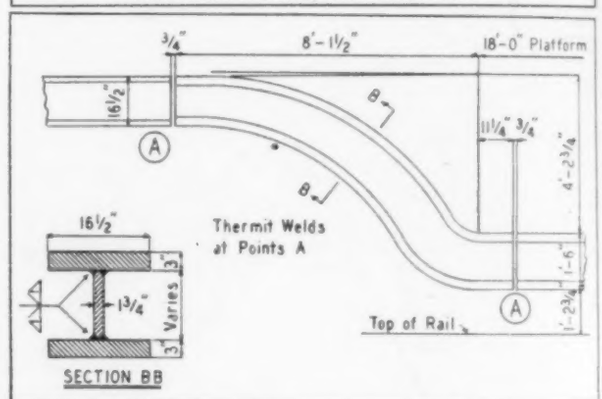
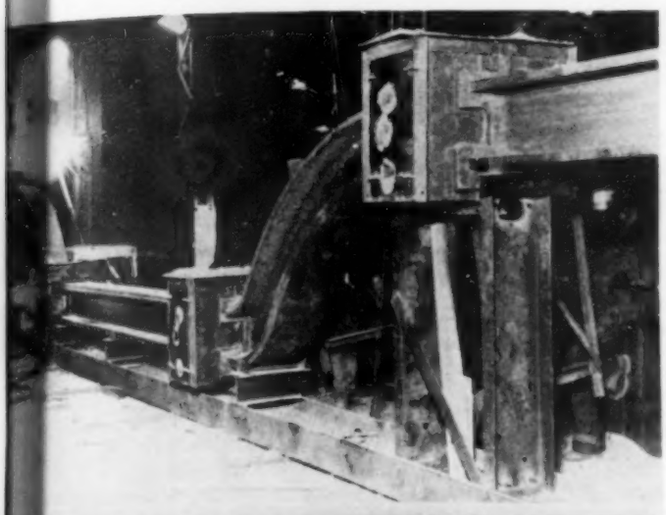


Fig. 3

Fig. 4—Jig and Assembly for Thermit Welding



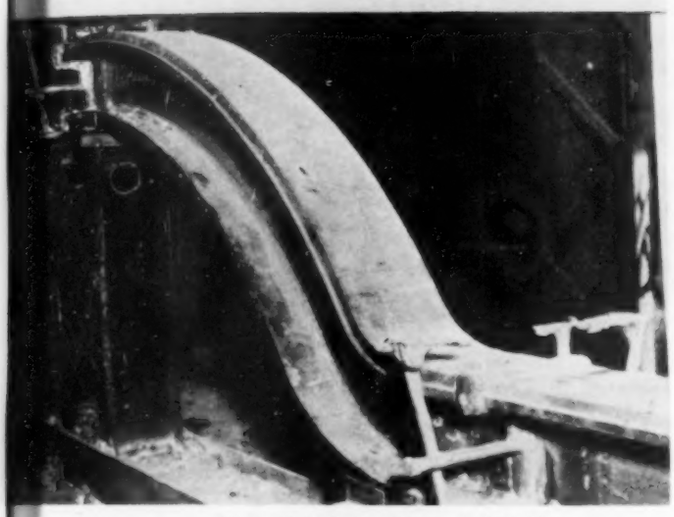


Fig. 5—Joint After Removal of Mold

forcing plate added to balance the section and bring the stresses within the working range. The distribution of the load among the seven beams was based upon the moments of inertia of the individual beams and was a matter of considerable calculation before a satisfactory balance was obtained.

A clear idea of the sizes of these beams can be obtained from the following table of their dimensions.

Table 1

Beam Size	Depth, In.	Flanges Width, In.	Flanges Thickness, In.	Web Thickness, In.
14 CB 370	18	$16^{1}/_{2}$	$2^{11}/_{16}$	$1^{11}/_{16}$
14 CB 426	$18^{3}/_{4}$	$16^{3}/_{4}$	$3^{1}/_{16}$	$1^{7}/_{8}$

One of the first problems that arose in the design was the selection of a working stress. As everyone, who is familiar with rolled steel, knows, it is impossible, without increasing the amount of carbon and other alloying elements, to secure in such heavy sections the same strength properties that are normally obtained on material of lighter and more usual thicknesses. Since these beams were to be spliced and joined together by welding it was decided to limit the carbon to 0.20 max. and accept a lower yield point. Ordinarily, the selected analysis of nickel-copper structural steel would give a yield point of 50,000 lb. per sq. in., but in these thick beam sections the mills would not guarantee a minimum of more than 40,000 lb. per sq. in. The actual values of the yield point of the material, as rolled, ran about 42,000 lb. per sq. in.

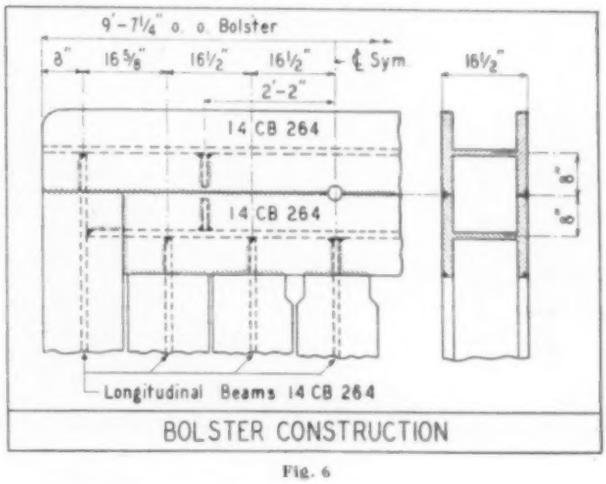
It was evident that there was no practical way to bend a single beam of such size into the curved shape of the main car body. There were distinct advantages in dividing each longitudinal beam into five parts—the straight platform portion, the two curved transition sections and the two straight end sections. For the curved portions it was decided to build up the sections as shown in Fig. 3. One incidental gain from this division of the beams into five sections was the possibility of using lighter beams for the end portions to effect some considerable weight saving.

The method of welding these five sections into one beam had to be given serious thought for several reasons. Owing to the distribution of loading, the stresses at the splices between the platform and the curved sections are about 81% of the maximum stresses at the center. This called for practically 100% efficiency in the splices. Another factor was the impossibility of stress-relieving the completed structure—first, because of lack of facilities of sufficient size and second for fear of distortion. Distortion from the welding alone had to be guarded against since all seven beams had to have the same shape, otherwise the platform would not be smooth and level when the final assembly was made. When one considers the 109 square inches of beam section to be spliced, the number of passes to be made by the arc welding method and the number of turns of the beam to position the welding, it is realized that there were difficulties in the way of obtaining uniform results on a series of beams and any straightening to achieve uniformity would be extremely difficult.

The weights and sizes of the parts to be handled were also a factor to be considered. The following table lists these weights for one of the interior beams.

1—Platform Section	@ 5970	= 5970 lb.
2—Curved Sections	@ 4360	= 8720
2—End Sections	@ 2485	= 4970
Total Weight of One Beam		= 19660 lb.

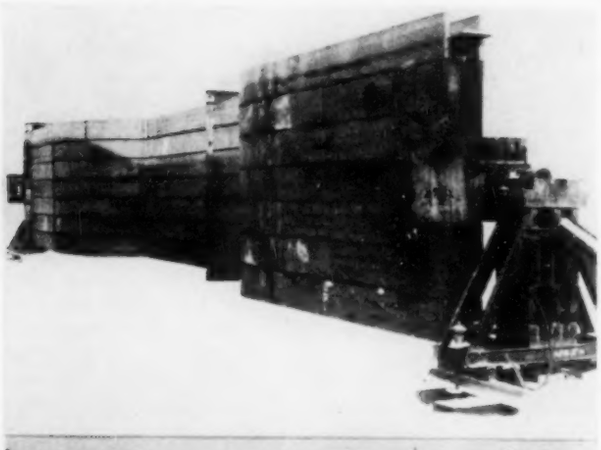
The assembled beam, about 56 ft. long, with ends curved upward to an offset of 4 feet 3 inches, would have been an awkward and heavy piece to position for welding on all four sides of each splice. Then too, only one car was to be built and any considerable expenditures for special handling were not warranted.



BOLSTER CONSTRUCTION

Fig. 6

Fig. 7—Jig for Assembly of Car Body



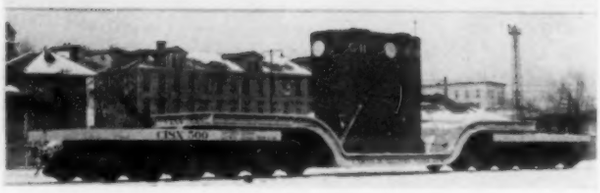


Fig. 8—Car Loaded with Mold Weighing 160 Tons

Thermit welding offered an excellent solution of the problem of making these splices. The weld is made in one operation so that heating and subsequent shrinkage are uniform across the section. Then the mold around the joint provides for slow cooling, which is practically a stress-relieving process, resulting in a minimum of locked-up stresses. Accordingly, thermit welding, was adopted for making all the splices. There were 28 joints to be welded and the molds were practically alike for all of them, therefore making a good production job.

Before describing the set-up for the thermit welding, let us take up briefly the welding of the curved transition portions. It would have been a formidable job to press such a heavy beam section into the S-shape, so the decision was made to build this section from plates or slabs. The webs were cut to shape by a gas torch, mechanically guided from a track template. The edges were then beveled to a depth of $^3/_4$ inch to provide a double Vee for welding. The top and bottom flanges were bent to shape and checked against a template. Then the web and flange plates were assembled in a jig and welded together in eight alternate passes on each side of the web. Three-quarter inch fillets were then built up on top of these welds in six passes on each side. During the welding, the steel was kept warm with gas flames.

Figure 4 shows the jig and arrangement for assembling and thermit welding the longitudinal beams. The picture shows one of the interior beams of the main car body. Each of the five parts was assembled in its proper position and the molds were placed around the four splice joints. This operation required a day's time. On the second day, the joints were preheated, two at a time, and then poured. In the meantime, another beam was assembled on a second jig and the fabrication alternated from one jig to the other. The ends of the beams at the joint were cut square and their faces separated $^3/_4$ of an inch. Figure 5 shows two of the joints after removal of the molds. Subsequently, the reinforcing was chipped and ground along the edges of the flanges and smoothed over the remaining portions of the joint. At this point it may be interesting to know that the overall movement of the beam, after the four splices had been poured and cooled, was negligible.

The calculated deflection for the fully loaded car indicated a value totaling $3^1/_2$ inches. It was deemed advisable to provide a 2 inch camber, which was done by assembling the two end portions with downward slopes from the splices to the ends.

The next step in the fabrication was the assembling and welding together of the seven beams comprising the main car body. The ends of the beams are framed into double-beam bolsters as shown in Fig. 6. When finally fabricated, the top and bottom flanges of the beams in the platform and curved portions were securely welded together as indicated in Fig. 2. J butt welds were used in order to avoid moving all the heavy pieces to a machine for preparation of the groove, since the placing of a groove in each edge of the flanges of only three beams provided grooves for welding all of the beam flanges together. This machining was done on the individual

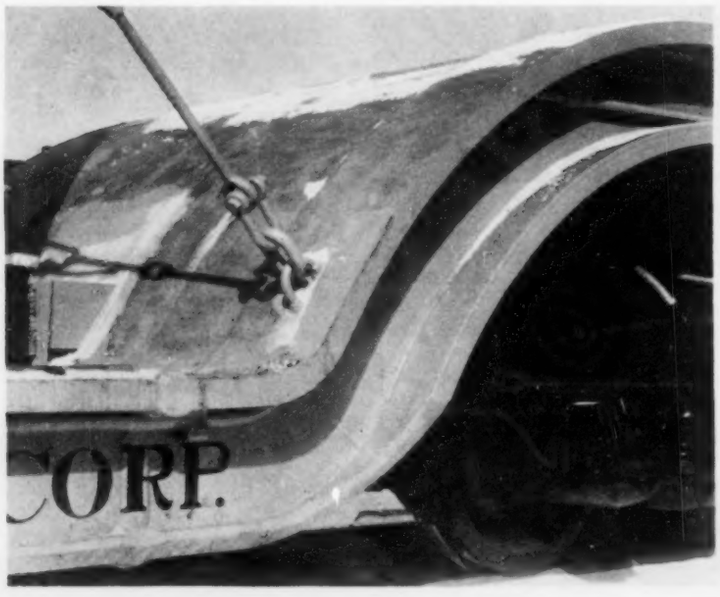


Fig. 9—View of Thermit Welded Splice

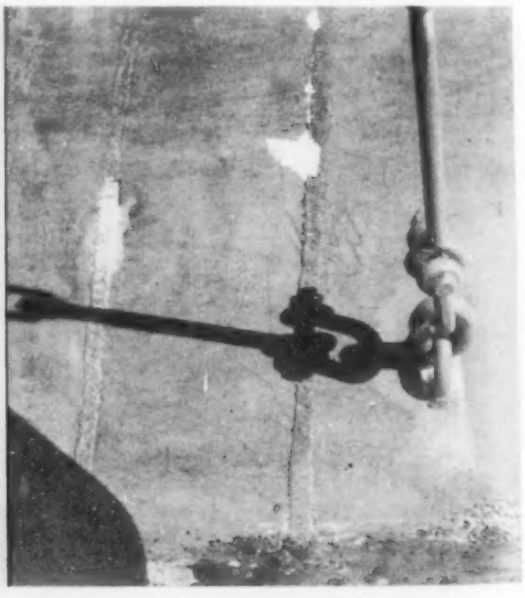


Fig. 10—Longitudinal Welds on Curved Section

units of the beams before the thermit welding of the splices was carried out. The prepared edges are clearly shown in Figs. 4 and 5.

When the main car body was completely assembled its weight was about 148,000 lb. Welding of both top and bottom flanges called for some means of turning the heavy structure so that the work could be positioned for welding. A jig with trunnions and a clamp for holding the bolsters was constructed and is shown in Fig. 7. Since the connections of the ends of the beams to the bolster are boxed in by the addition of the next beam, it was necessary to start with the assembly of the middle beam and weld it to the bolsters at each end. Then the beams on either side were assembled and welded to the bolster until, finally, all seven beams were so connected.

Next came the making of the continuous longitudinal welds on the flanges of the beams in the platform and curved sections. The entire assembly was maintained at about 200° F. throughout this welding operation. By a careful control of the heat it was possible to keep warping to a minimum. Gages were distributed at several points, by means of which the deflection due to welding on the top side could be measured. Whenever this deflection amounted to $^1/_2$ inch the assembly was turned over and welding proceeded on the opposite side until the deflection indicated that another reversal should be made. Once the welding had begun, the operation was carried on continuously until the work was completed. The step-back method was followed and symmetry of welding was maintained in order to avoid unequal warping.

Upon the completion of the longitudinal seams, the positioning fixtures were temporarily removed to permit the addition of the outside end beams forming the other half of the bolsters. The fixtures were replaced so that the final welding of these end beams could be completed and the body side bearings be positioned. The jigs were then removed and the center plates riveted and welded in place. From this stage on, the assembly of the car was completed by placing the main body on the two end car structures.

A few statistics in regard to the welding may convey a good idea of the size of the job. In the making of the 28 splices, 8000 lb. of Thermit were used. There were 38,400 linear feet of $^1/_4$-inch bead welding, requiring 7800 lb. of electrodes and 1400 man-hours for the operators.

Figure 8 is a photograph of the completed car carrying an ingot mold weighing 160 tons. In Figure 9 there is a closer view of the thermit-welded splice between the platform and curved portions. The beveling of the bottom flange to bring it within the A.A.R. clearance diagram is plainly seen. Likewise, the fillet weld between the web and flange of the curved section is distinct. Figure 10 shows the longitudinal seams on the flanges of the curved beams.

The car was built by the Greenville Steel Car Company at Greenville, Pa. under the personal direction of Mr. W. S. Dietrich, Vice-President, who devised the ingenious methods of handling these heavy pieces.

The thermit welding, as well as the fusion welding, was conducted by the Metal & Thermit Corporation under the direction of Mr. Harry T. Thompson, District Manager in Pittsburgh.

(*Continued from page 723*)

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Welding Society

ACTIVITIES — Related Events

PRESIDENT'S MESSAGE

The most important week of the year to a technical society is that of its annual meeting. A very large proportion of society activities go into the preparation for and organization of that event. Like the flower of the plant, it is the culmination of the unspectacular growth processes of the seasons.

In an industrial civilization, the specialized technical society represents an organized portion of the consciousness of each of its members. In the body politic it is an organ highly functionalized to render certain services.

With each individual member, the question will arise as to how he can afford, even for a few days, to leave his immediate job which demands more and more production efforts.

The human being is not merely a mechanism in which the output is a matter of hours. Some of us may have positions which demand our presence only and utilizes not at all our capacity for thought. Fortunately, there are few positions of that type for the engineer. For his work, full creative capacity is needed. How much he creates depends upon the force that lifts him from the narrow horizon of his individual efforts.

There are many sources of inspiration. One is contact with others of broader horizons or even of horizons adjacent to our own. In the discussions that follow, relationships that were so obscure suddenly become apparent, difficulties that blocked solution vanish and missing links appear in the accomplishment of others. Another source of inspiration is the contact with those who are carrying on development work. The ideas obtained in contacts with them may furnish the solution to some problems which, in our limited experience, have appeared unsolvable.

There is no other place or time at which these contacts are so readily made as during the annual meeting of a technical society.

Even though some time is consumed, the individual engineer cannot afford to miss the inspiration that comes from these gatherings.

NATIONAL METAL CONGRESS AND EXPOSITION

The National Metal Congress and Exposition, combining the metal world's largest industrial exhibit and sessions for principal technological societies dealing with metals, will meet in Philadelphia for five days beginning October 20th.

The 1941 Congress and Exposition will be the largest in the twenty-three year history of the event according to Wm. H. Eisenman, managing director. More than 105,000 square feet of exhibit space has been taken by exhibitors representing every branch of the metals and associated industries. Extensive technical programs of the American Society for Metals, the AMERICAN WELDING SOCIETY, the Wire Association and the Iron and Steel division and the Institute of Metals division of the American Institute of Mining and Metallurgical Engineers will be held in conjunction with the show. Technical sessions are generally scheduled to be held in Philadelphia hotels as well as at the larger meeting rooms in the Convention Hall.

The theme of the 1941 National Metal Congress and Exposition is "New Aids to National Defense Production"—an especially appropriate keynote by virtue of the gigantic defense program now under way. Every item and method to be seen will have direct relation to the preparedness program.

The welding industry will be represented at the metal show by all types of welding: arc, spot and resistance; by gas welding and oxyacetylene gas and gas cutting equipment. Included in this group are electrodes and electric controllers as well as various grades of welding wire for gas and electric welding.

Heat-treating furnaces of all types will be on display: salt bath, annealing-electric, gas and oil fired; induction, atmospheric controlled furnaces of all types and sizes. In addition there will be furnaces and heating equipment for heating rivets and bars; industrial oil-heating apparatus and various insulating materials for furnaces and electric heating elements.

In steels visitors will see tool steel, stainless steel, construction steel, valve steel for aircraft and automotive units, heat- and corrosion-resistant alloys, sheet, strip and high-speed and other steels. These will be shown in finished form and through products made from them.

In the non-ferrous field there will be aluminum, aluminum alloys, magnesium, magnesium aluminum alloys, copper, brass bronzes, zinc, die casting shapes and forms, non-ferrous wire and other alloys cast and wrought. Machinery for die casting, wire drawing and spring forming will be shown.

Testing equipment to indicate hardness, tensile, torsional strength, fatigue and many other properties of metals will be demonstrated.

Temperature recording and control equipment will include devices for indicating, recording and controlling temperatures.

Fastener items to be shown include nuts, bolts, screws, rivets and lock washers. Hard-surfacing alloys for various parts of industrial machinery will be on display.

Petroleum products, quenching oils, rust preventatives and metal-cleaning compounds will be shown. Sand-blast equipment and detergents will be included.

Industrial appliances to be shown will include safety shoes, masks, goggles and other safety equipment as well as water-dispensing equipment.

X-ray equipment, turbo compressors and metal cloth are included in the miscellaneous classifications.

Trade and business publications in the metals and associated fields have made arrangements to provide various informational services at their exhibit booths.

Grade and professional associations, allied with the metals field, will be represented by exhibit booths.

Technical programs arranged by the four societies are larger this year than ever before.

Approximately 60 papers are tentatively scheduled for presentation by the AMERICAN WELDING SOCIETY in its general sessions and in its industrial and fundamental research groups. Headquarters for the A. W. S. will be at the Bellevue-Stratford Hotel.

The American Society for Metals' technical program will present 60 papers in fourteen sessions and will include a symposium on "Controlled Atmospheres"—a lecture course to be presented on Thursday and Friday mornings. The A. S. M. National Defense Meetings are described in the accompanying material.

The annual fall meeting of the two metals divisions of the American Institute of Mining and Metallurgical Engineers, held during the first three days of the Congress, will feature joint and simultaneous sessions, committee meetings and a round-table discussion on "Order-Disorder Phenomena." Headquarters for the Institute will be at the Ritz-Carlton Hotel.

The Wire Association will present an interesting motion picture, "Wings of the Army," in addition to a select list of technical papers and discussions. Headquarters for this society have been announced for Hotel Philadelphian.

This year's National Metal Congress and Exposition will be the largest in history. Hotel reservations are being made direct with hotels in Philadelphia.

The 1940 high of 35,000 attendance is expected to be exceeded at the National Metal Congress and Exposition for 1941.

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Electrode manufacturers, along with many others having a part in defense production, are faced with the problem of maintaining the prompt deliveries to which customers are rightfully entitled.

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Because of these conditions we earnestly urge all users of electrodes ***to order electrodes when they order their steel.*** Requirements are generally known at that time and by ordering without delay embarrassing delays due to electrode shortage may be avoided.

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OUR PRESIDENT

Glen F. Jenks

Our incoming President succeeds himself as President of the AMERICAN WELDING SOCIETY. Colonel Jenks has been active during the year in many of the affairs of the SOCIETY, notably its technical and research work. In addition, he has found time for the presentation of papers before various Section meetings. During the coming year there is every reason to believe that the steady progress of the SOCIETY will continue onward under his guiding hand.

Glen F. Jenks

Colonel Jenks was born at Deansboro, N. Y., June 13, 1880. Graduate of Hamilton College (Clinton, N. Y.), B.S. 1901, M.S. 1904. Graduate of Army War College (1924) and of Harvard Business School (M.B.A. 1930). Entered the Army as a 2nd Lieutenant, Artillery Corps, 1901, and detailed in the Ordnance Department, 1903. During the World War served as Colonel, National Army, at Headquarters A. E. F., and at Headquarters Service of Supplies A. E. F. in charge of technical work in heavy artillery in the Office of the Chief Ordnance Officer and for two months prior to the Armistice as Chief Ordnance Inspector of Artillery at Headquarters First Army. Was decorated by the French Government as Officer of the Legion of Honor and was awarded the Distinguished Service Medal by the American Government.

Since the war served in the Office of the Chief of Ordnance in charge of engineering and production of artillery material, and later in the 8th Corps Area as Chief Ordnance Officer, and at Rock Island Arsenal for two years as Production Manager. Was at Watertown Arsenal as Director of Research for two years and then in command from 1932 until 1937, when assigned to duty in the office of the Chief of Ordnance, U. S. Army. Promoted to the grade of Colonel, Ordnance Department, November 1, 1933.

Member of A. W. S., A. S. M. E., A. I. M. E., A. S. M., A. S. T. M. and S. A. E. Fellow A. A. A. S.

Member of Engineering Foundation Welding Research Committee and Chairman Industrial Research Division of that committee. Member of the Joint Research Committee on Effect of Temperature on the Physical Properties of Metals and of various technical committees of the A. W. S., A. S. T. M. and A. S. A. Chairman of A. S. T. M. Committee E-9 on Research.

Vice-President A. W. S. 1937–1939 and Director-at-large A. W. S. 1939.

President of the A. W. S. 1940–1941.

OUR FIRST VICE-PRESIDENT

Klaus L. Hansen

Klaus Lobeck Hansen, consulting engineer, Harnischfeger Corporation, Milwaukee, Wis., has been re-elected to serve as the First Vice-President of the SOCIETY. He was born in Sandefjord, Norway, September 14, 1882, and came to the United States in 1901. He was employed by the National Stamping Works and the Western Electric Company, both at Chicago, Ill., before entering the University of Illinois where he studied electrical engineering 1903–1905. After several months with the Chicago Edison Company, he was employed by the Westinghouse Electric and Manufacturing Company, East Pittsburgh, Pa., in 1906 and continued with the company until 1919, his last position being designing engineer on D.C. apparatus.

While in the employ of theWestinghouse Company Mr. Hansen became interested in design of arc-welding generating equipment. In 1916 and 1917 he worked on design of constant potential generators, and somewhat later developed and designed the first single-operator set marketed by the Westinghouse Company. In 1919 he went with the Mechanical Appliance Company (later the Louis Allis Company), Milwaukee, as designing engineer, later becoming chief engineer. He left the company in 1921 to engage in consulting and development work on his own patents. He invented the Hansen arc welder, and in its manufacture and sale was associated with the Northwestern Manufacturing Company, Milwaukee, from 1924 to 1932, when it was taken over by the Harnischfeger Corporation. He holds patents on various arc-welding processes and joint patents on induction motors, and has published a number of technical papers, chiefly concerned with welding. He has been a member of the Institute's electric welding committee 1930 to date (chairman 1932–1934), was chairman of the Milwaukee Section 1933–1934, and chairman of the 1937 A. I. E. E. summer convention committee.

Klaus L. Hansen

OUR SECOND VICE-PRESIDENT

David Arnott

David Arnott

Mr. Arnott who succeeds himself for another year in the post of Second Vice-President has been active in the SOCIETY since its early days, particularly in its technical activities relating to ship welding. He has delivered a number of papers before the various Sections of the Society and is author of an important chapter of the Welding Handbook. Mr. David Arnott has been a strong supporter of the research activities of the SOCIETY and at the present time is Chairman of the A. W. S. Committee on Welding in Marine Construction. He has also served on the Executive Committee of the Society.

Mr. Arnott was born in Glasgow, Scotland, 1878. He is a graduate of the Royal Technical College, Glasgow, and received his apprentice training as a ship welder with the Fairfield Shipbuilding & Eng. Co., Ltd., Glasgow. He has served as Surveyor, British Corporation Register of Shipping and Aircraft from 1901 to 1917, at head office in Glasgow. He was also Principal Surveyor for Canada, British

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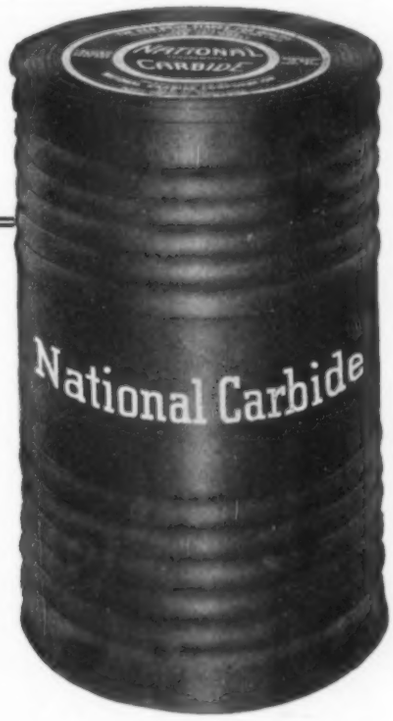

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Corporation Register of Shipping and Aircraft, from 1917 to 1918, stationed at Toronto. Later he became Deputy Chief Surveyor, American Bureau of Shipping, from 1918 to 1925, New York. In 1925 he became Chief Surveyor of the American Bureau of Shipping, a position which he holds at the present time. To these duties were added those of Vice-President of the American Bureau of Shipping in 1938, which position he also now holds.

His technical society affiliations are quite numerous and include: Council Member, Society of Naval Architects & Marine Engineers; Member, Institution of Naval Architects; Member, British Institute of Welding; Technical Advisor to U. S. Delegation, International Safety of Life at Sea Convention 1929; U. S. Delegate to International Load Line Convention 1930. Mr. Arnott became a naturalized citizen of the U. S. A. in 1924.

O. B. J. Fraser

OUR NEW TREASURER

O. B. J. Fraser

Mr. O. B. J. Fraser is relatively a newcomer with the AMERICAN WELDING SOCIETY, having joined in 1935. In this short space of time he has established himself as one of the hardest workers of the SOCIETY. He is Chairman of the Nickel Alloys Committee of the Welding Research Committee. He has served as a member of the Executive Committee of the SOCIETY and a member of the Committee on Outline of Work. He served also as chairman of the Meetings and Papers Committee and of the Committee to Study the Reorganization of the Technical Activities of the SOCIETY. His good judgment and genial disposition and his broad experience make him a decided asset to the SOCIETY as its new Treasurer.

O. B. J., as his friends choose to call him, was born in Brockville, Ontario, Canada. He received B.Sc. degree in Metallurgical Engineering in 1916 from Queen's University, Kingston, Ontario. He spent a year inspecting military explosives. He joined the International Nickel Co., Inc., in the summer of 1917 at their works in Bayonne, N. J. From then until 1922 he occupied several positions at the Port Colborne, Ontario, Works of the company, as superintendent of the electrostatic fume precipitation plant, as night works superintendent and research engineer. In 1922 and 1923 he became connected with Mellon Institute in the study of corrosion of nickel and nickel alloys. From 1924 to 1932 he was in charge of the research laboratories of the International Nickel Co. at Bayonne. From 1933 to 1934 he carried on field development work in the use of nickel alloys in the petroleum industry. From 1934 to date he has served as Director of Technical Service on the International Nickel Company's mill products, which include welding service work on nickel, nickel-copper and nickel-chromium iron alloys and on steel clad with these alloys.

OUR DISTRICT VICE-PRESIDENTS

New York and New England—Edwards R. Fish

Mr. Edwards R. Fish, New York and New England District Vice-President, prepared for college at the St. Louis Manual Training School and was graduated from Washington University in St. Louis with the degree of Mechanical Engineering. After brief periods of employment in charge of the University Testing Laboratory and the street rail-

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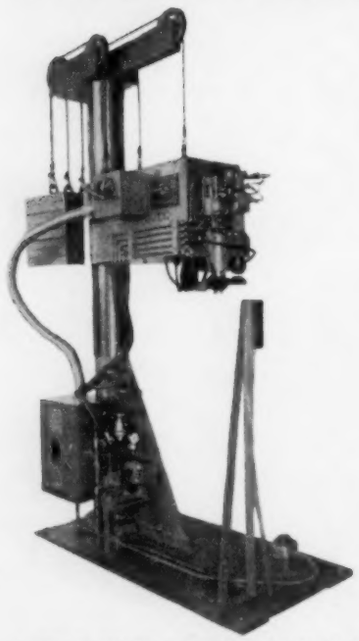

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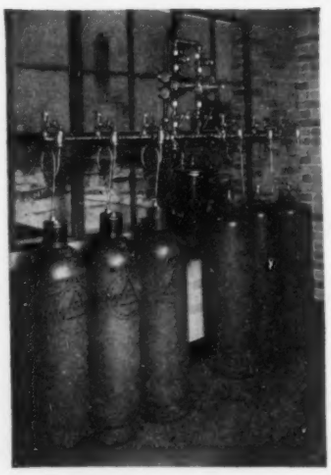

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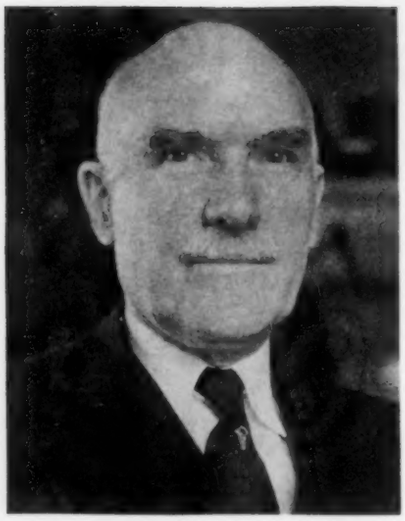

E. R. Fish

way department of the General Electric Company, he became associated with the Heine Safety Boiler. With that company he served in practically all departments gaining a wide experience in the design, manufacturing, sales and operation of boilers and pressure vessels. While in charge of the boiler shop he became interested in welding and used it to a limited extent. As a member of the A. S. M. E. Boiler Code Committee he had a large part in formulating the requirements for welded construction by which the use of welding for boilers and pressure vessels was formally recognized by the Code Committee.

Since joining the AMERICAN WELDING SOCIETY he has been active on several committees and interested in the promotion of welding in the construction of structures of all kinds.

He participated in the organization of the Connecticut Section of the SOCIETY and was its first Chairman.

He is at present Chief Engineer of the Boiler Division of the Hartford Steam Boiler Inspection and Insurance Company.

Middle Eastern—A. G. Bissell

Mr. Bissell has been elected Vice-President of the Society representing the Middle Eastern District.

A. G.'s first connection with welding dates from May 20, 1918, when he was detailed to investigate arc welding and its possible use in naval construction at the Puget Sound Navy Yard. As Metallurgist for that Navy Yard, he carried on the early development work, training of operators and organization of the Hull Division Welding Shop. While at that Yard, he prepared a thesis, "The Application of Arc Welding to Steel Ship Construction," which was presented in June 1920 to the University of Washington, Seattle, in fulfillment of the requirements for the Degree of Chemical Engineer. It is believed that this was the first thesis on welding to be

A. G. Bissell

accepted for an advanced degree. Curiously enough, Mr. W. Spraragen, Technical Secretary of the SOCIETY, who was teaching at the university at that time, was in charge of this thesis.

The sojourn at the Navy Yard was completed in October 1921. The next major connection involving welding occurred on March 23, 1923, when he entered the General Engineering Department of the Westinghouse Electric & Mfg. Co., at East Pittsburgh, as an arc-welding engineer. On this job he did considerable work on the

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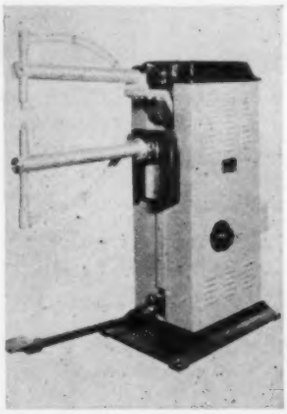

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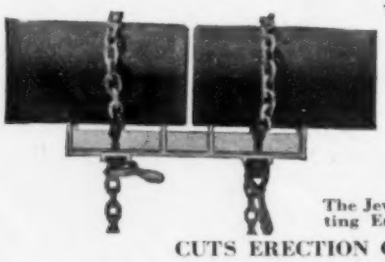

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early development of structural steel welding, participating in the design and erection of the first all-welded buildings at East Pittsburgh, in July 1926, and the first all-welded through plate girder railroad bridge at Turtle Creek, Pa. During his connection with Westinghouse he spread the gospel of arc-welded structural steel and automatic arc welding throughout the country from Boston to Los Angeles, and Norfolk to Seattle. The Westinghouse connection ended in November 1928 when Bissell decided to break into the consulting game on the Pacific Coast. His next connection was with the Star Machinery Company of Seattle, as Sales Engineer, handling Westinghouse welding equipment.

His present connection with the Bureau of Construction and Repair was made on October 15, 1936. At the present time he is in charge of the supervision of the Welding and Castings Section of the Bureau of Ships. A. G. has served on literally dozens of important technical committees of the AMERICAN WELDING SOCIETY. He was one of the prime movers in organizing the Washington Section of the A. W. S. and a strong factor in building it up to its present unique high standing. He has assisted in the lecture course presented by the Washington Section. The Society last year elected Mr. Bissell as a member of the Board of Directors.

* * *

Middle Western—Leslie S. McPhee

Leslie S. McPhee, newly elected Middle Western District Vice-President, was born in Chicago on February 22nd, 1904. He attended the Thornton Township High School, the Alexander Hamilton Institute, the International Correspondence School and the Armour Institute of Technology, Civil Engineering Department. He had a four years' Engineering Apprentice Course at the Whiting Corporation and was Engineering Representative for this same company for four years. For the past ten years he has been Supervisor of Welding for Whiting Corp.

L. S. McPhee

Mr. McPhee was Director of the Chicago Section for three years from 1936 to 1939; from 1939 to 1940 he was Vice-Chairman of the Section and from 1940-1941 he was Chairman of the Chicago Section.

* * *

Southern—J. A. Hall

Our new Southern District Vice-President, Mr. J. A. Hall, is connected with the Kansas City Structural Steel Company. He started with this company on December 1, 1913, as structural steel detailer, checker, manager tank department, and at present he is contracting engineer in charge of steel construction, with the title, Engineer of Steel Plate Construction.

Mr. Hall was born on a farm near Monte Vista, Colorado, January 27, 1888. He graduated in 1911 from the University of Colorado with the degree of Bachelor of Science in Civil Engineering.

One of his positions was as structural steel detailer with the American Bridge Company. Later he became assistant foreman of highway bridge erection at North Bend, Nebraska, for Stupp Broth-

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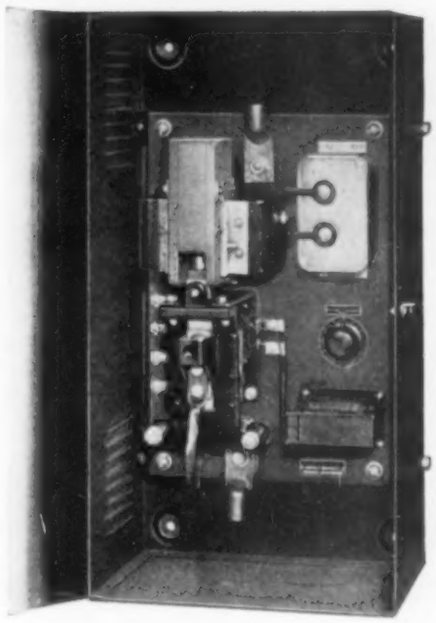
Rods from 1/8" to 1/2" in diameter—and in six grades of strength, from 50,000 to 80,000 p.s.i., and hardness from 100 to 387 Brinell—easily used with metallic arc, carbon arc or oxy-acetylene processes, on all steel, cast iron, brass, bronze, and nickel alloys.

GET COMPLETE DATA

Write for new bulletin giving full details of physical properties and applications of AMPCO-TRODE. Our engineers are at your service.

AMPCO-TRODE
A product of
AMPCO METAL

No ARCING or BURNING of CONTACTS with this new *Syncro-Break* CONTACTOR



● If an AC circuit is broken at the zero point on the load current wave, there can be no arcing. Because the Square D *Syncro-Break* contactor always breaks at that point, burning of contacts is eliminated and higher ratings are made possible. The first cost of the equipment is low and maintenance is reduced to a minimum.

The syncro-break principle, when applied to a special contactor and used with a synchronous motor driven precision timer, provides accurate timing periods as short as one-half cycle.

Inexpensive, easily installed and operated, the precision control permits welds heretofore practical only with costly and intricate equipment.

Write to the Square D Company, Milwaukee, Wisconsin, for an interesting bulletin on "Resistance Welding."

CALL IN A SQUARE D MAN

SQUARE D COMPANY
INDUSTRIAL CONTROLLER DIVISION
4041 N. RICHARDS ST., MILWAUKEE, WIS.

J. A. Hall

ers Bridge and Iron Company. In 1913 he served as draftsman for Stone and Webster and with the Leonard Construction Co.

Mr. Hall is well known to the members, having been chairman of our Kansas City Section.

* * *

Pacific Coast—N. F. Ward

Our New Pacific Coast District Vice-President is one of the most active members in the Society. He has written numerous articles on spot welding research, arc and gas welding, appearing in THE WELDING JOURNAL and the *S. A. E. Journal, Industry and Welding, Metallurgy in Metals and Alloys,* and *Transactions of American Society for Metals.*

Prof. Ward has distinguished himself as a consulting welding engineer and teacher of engineering. He was born in Lockport, N. Y., January 28, 1897. He served as Instructor in Mechanical Engineering at Cornell University 1921–27. He was Assistant and Associate Professor of Mechanical Engineering at University of California from 1927–41. He was visiting lecturer of welding and metallurgy at Boeing School of Aeronautics since its founding in 1929. He was author with Prof. J. E. Younger and A. F. Bonnalie of texts "Airplane Construction and Repair," "Structural Design of Metal Airplanes" and "Airplane Maintenance."

He has acted as consultant welding engineer for the American Tractor Equipment Co., Roe Welders, Brodie Meter Co., and Engineers Ltd. from 1934–40. He is a member of numerous organizations, including the Institute of Aeronautical Sciences, AMERICAN WELDING SOCIETY, American Society of Mechanical Engineers and American Society for Metals. He has served as Vice-Chairman and Chairman of the San Francisco Section of the A. W. S. He was Chairman of the Program Committee of the San Francisco Section of the A. S. M. E. in 1941. He is Lieut. (jg) U. S. N. R. since 1937; member of Delta Chi fraternity, Tau Beta Pi, national honorary engineering society,

N. F. Ward

Sigma Xi, national honorary scientific society. His biography appears in *Who's Who in Aviation, Who's Who in Engineering* and *American Men of Science 1941.*

* * *

DIRECTORS-AT-LARGE

Fred L. Plummer

Mr. Plummer has an enviable record. He graduated from Ohio University in 1920 with the degree of Bachelor of Arts. In 1922, he obtained the degree of Bachelor of Science in Civil Engineering from Case School of Applied Science, and two

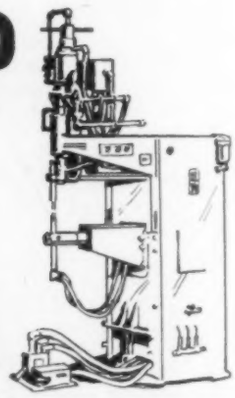
AIRFLOATED
RUTILE

For Welding Electrodes

Mining Brazilian Rutile

FOOTE
MINERAL COMPANY
1612 Summer St. Philadelphia, Pa.

SPEED-UP SPOT WELDING



NEW Oakite cleaning process for aluminum helps you get MORE welds in less time!

If you are spot welding aluminum alloy structures or assemblies, you can easily SPEED-UP PRODUCTION by using a newly developed, practical Oakite process that successfully prepares metal surfaces for this operation. Interesting data mailed FREE to those requesting it on their business letterhead.

OAKITE PRODUCTS, INC., 18E Thames Street, NEW YORK, N. Y.

OAKITE *certified* CLEANING
MATERIALS & METHODS FOR EVERY CLEANING REQUIREMENT

The Resistance Welder Manufacturers' Association Extends to all visitors to the Metal Show a cordial and hearty invitation to drop in our booth,

A-6

and rest your tired and weary feet. Here you will find pleasant and congenial surroundings, meet friends you haven't seen since the last show—talk about Golf, Your Vacation, Hitler, Priorities—and you can even discuss that pressing welding problem. If you need passes, just call our office—phone Lombard 8895—and they will be promptly and cheerfully mailed you.

Resistance Welder Manufacturer's Association

505 Arch Street Philadelphia, Pa.

MEMBER COMPANIES

Acme Electric Welder Company, Los Angeles, Calif.
Eisler Engineering Company, Newark, N. J.
Expert Welding Machine Company, Detroit, Mich.
Federal Machine and Welder Company, Warren, Ohio
Multi-Hydromatic Welding and Manufacturing Co., Detroit, Mich.
National Electric Welding Machines Co., Bay City, Mich.
Progressive Welder Company, Detroit, Mich.
Swift Electric Welder Company, Detroit, Mich.
Taylor-Hall Welding Corporation, Worcester, Mass.
Taylor-Winfield Corporation, Warren, Ohio
Thomson-Gibb Electric Welding Co., Lynn, Mass.
Welding Machines Mfg. Company, Detroit, Mich.

ASSOCIATE MEMBER COMPANIES

P. R. Mallory and Co., Indianapolis, Ind.
S-M-S Corporation, Detroit, Mich.
Electroloy, Inc., New York, N. Y.
Welding Sales and Engineering Co., Detroit, Mich.

years later obtained the degree of Master of Science in Civil Engineering from the same university. He is a registered engineer in Ohio and New York.

F. L. Plummer

During a period of 14 years (1923–1937) he was Instructor in Mathematics and Civil Engineering, later becoming Associate Professor of Structural Engineering at Case School of Applied Science. During the greater part of this period, he also lectured on mechanics, strength of materials and structural design at the Cleveland School of Architecture of Western Reserve University.

He was also a lecturer for an eight-year period from 1932 to 1940 at the John Huntington Polytechnic Institute on soil mechanics and foundation, as well as advanced structural design. He was in charge of or associated with structural analysis and design of such structures as the world's largest airship dock for the Goodyear Zeppelin Corporation, a seven million dollar steel bridge and a million dollar reinforced concrete bridge. He has also served as consultant and technical advisor with such companies as Truscon Steel Company, Republic Steel Company, Goodyear Zeppelin Corporation, Dow Chemical Company, Corrigan-McKinney Steel Co., International Bridge Company, Leo C. Moore & Co. and National Steel Barrel Co. He has also served the Government as consultant in connection with earth dams, soil mechanics, structural models, earthquake stresses in dams and bridges. He also organized the engineering staff to prepare plans for the construction of the Main Avenue Bridge project of Cuyahoga County. The complete project cost about eight million dollars. It included two small, all-welded bridges, the first in the Cleveland area.

From 1940 to date, he has been Chief Research Engineer of the Hammond Iron Works, Warren, Pennsylvania, and concerned with research development and special designs.

Mr. Plummer is a member of a great many societies and committees including such organizations as the American Society of Civil Engineers, American Society for Testing Materials, Highway Research Board and the AMERICAN WELDING SOCIETY; honorary scientific organizations: Sigma Xi and Tau Beta Pi.

As author and joint author, Mr. Plummer has written three books on structures, soil mechanics and foundations. He has written some forty papers and presented a great many addresses. Of special interest is a recent contribution in THE WELDING JOURNAL entitled "Shall We Weld Our Bridges?."

* * *

R. G. LeTourneau

Our new Director, Mr. R. G. LeTourneau, was born on November 30, 1888, in Richford, Vermont. He is President of R. G. LeTourneau, Inc., The LeTourneau Foundation, Louise Farming Co. Inc., and a number of other organizations, among which may be mentioned LeTourneau Machinists School, Toccoa Falls Flying School, WHEB, Inc. He is also owner of the Radio Station WRLC. He holds an honorary degree of Doctor of Engineering from John Brown University of which he is also a director. He is a member of the AMERICAN WELDING SOCIETY and the American Society of Mechanical Engineers. Mr. LeTourneau began his career as an iron molder in 1902.

R. G. LeTourneau

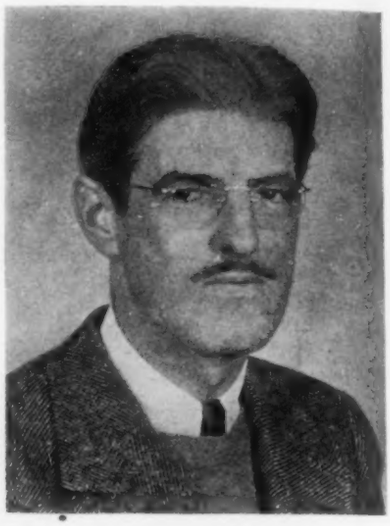
He was in the garage business for a period of ten years and during the World War was stationed at the Mare Island Navy Yard machine shop. After the War he became a contractor and built his own land-leveling equipment. This equipment was so successful and so much in demand that he gave up his contracting and expended his energies in the manufacture of heavy grade equipment.

Raymond Rich Associates' book entitled "American Foundations and Their Field," rank The LeTourneau Foundation as twelfth largest foundation and the largest religious foundation in the United States. Actual contributions made by The Foundation total $1,067,000. These contributions are in addition to activities carried on directly by The Foundation such as Tracts, "NOW," Bethany Camp, Lake Louise Camp, etc. Mr. R. G. LeTourneau has donated to The Foundation ninety-nine per cent of his worldly possessions. The Foundation has set up the LeTourneau Evangelistic Center in New York City with offices in Rockefeller Center. Some 23 evangelists work out of this office spreading the gospel all over the United States.

* * *

Frank B. Bolte

Mr. Bolte is a newly elected Director. He is one of the pioneers in aircraft construction. He attended the University of



Frank B. Bolte

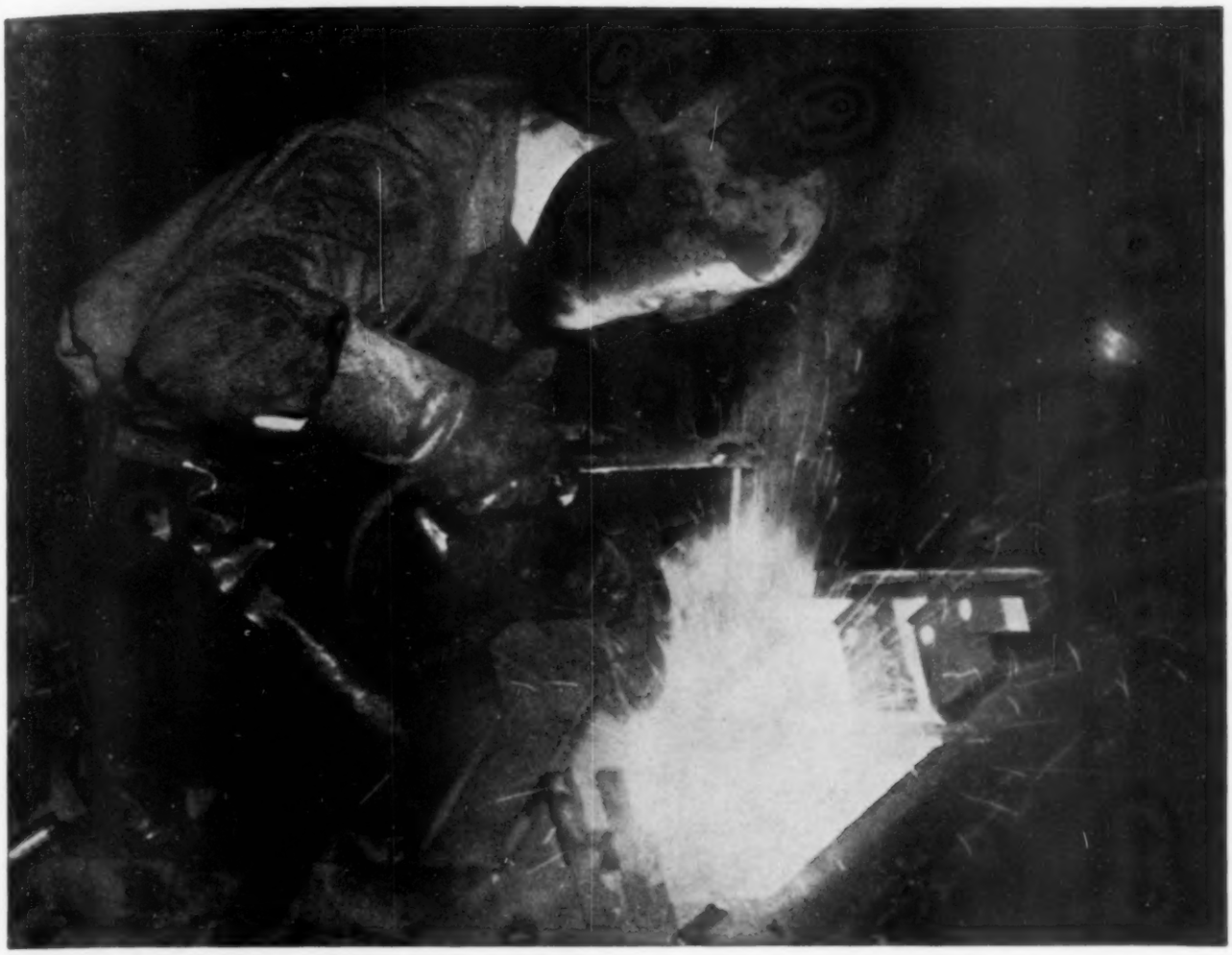
Illinois Mechanical Engineering Course and has had 17 years of aircraft experience with some eight aircraft companies. The most important of these from the point of view of length of service is the Douglas Aircraft Co., the Stout Metal Airplane Co. and the Boeing Aircraft Co. Mr. Bolte is employed by this last-named company as Process Standards Engineer. In this capacity he is particularly interested in the standardization of welding as an aircraft process.

* * *

Roger W. Clark

Our new Director, Roger Clark, was born in Paxton, Mass., in 1902 and attended Clark University in Worcester, Mass. Roger is one of the hardest committee workers of the SOCIETY. He is Chairman of the Committee on Outline of Work, Chairman of the Committee on Definitions and Chart, and member of half a dozen technical committees of the SOCIETY. He has also been active in standardization work of the A. S. A. and the A. S. T. M. He is past chairman of the Northern New York Section of the SOCIETY and has been a member of the Executive Committee of the SOCIETY during the past year.

Roger joined the General Electric Company when he left Clark University in January 1924. A year later he became identified with welding in the General



We can help you do a better welding job!

ROLLED steel construction, like many other production practices, has been subjected to intense study. And, as in other producing methods, there have been vast and important improvements. All along the American industrial front, many practices and methods which served in ordinary times are being shelved for newer and better ways.

If you have a problem—if you need help in anything embracing welding construction, we are equipped to help you. It's been the job of our experienced welding engineers to determine just where and how rolled steels will best serve in all types of welding construction. Our specialized knowledge equips us to offer a service to the welding industry which we believe is as important as the wide selection of U·S·S Rolled Steels we make.

Write today for more complete information and technical data — tell us your problem, or ask one of our experts to call. These men will gladly work with you—no obligation.

U·S·S ROLLED STEELS *for* WELDING

CARNEGIE-ILLINOIS STEEL CORPORATION, *Pittsburgh and Chicago*
COLUMBIA STEEL COMPANY, *San Francisco*
TENNESSEE COAL, IRON & RAILROAD COMPANY, *Birmingham*
United States Steel Export Company, New York

UNITED STATES STEEL

R. W. Clark

Electric Company and during the next three years he was active in production welding, supervision and inspection. In 1928 he entered the Works Laboratory and was assigned to the problem of setting up engineering standards on welding. He has also been active in training and qualification of welding operators and the development of welding procedures and procedure control for the General Electric Co.

STANDARD SPECIFICATIONS FOR ELEVATED STEEL WATER TANKS, STANDPIPES AND RESERVOIRS

Sponsored by
American Water Works Association and American Welding Society

These Specifications were recently revised and by action of the sponsor societies have been advanced from a tentative standard to a full standard. 45 pages, heavy paper cover, price 30¢ per copy.

Orders for these Specifications should be accompanied by check, money order or cash, addressed to: American Welding Society, 33 West 39th Street, New York, N. Y.

FUTURE MEETINGS AND CONVENTIONS

The AMERICAN WELDING SOCIETY will hold its twenty-second Annual Meeting at the Bellevue-Stratford Hotel, Philadelphia, during the week of October 19th. National Metal Exposition will be held at the same time in the Commercial Museum.

The American Petroleum Institute will hold its twenty-second annual meeting at the St. Francis and Palace Hotels, San Francisco, California, November 3rd to 7th.

The Society of Automotive Engineers will hold their Annual Meeting and Engineering Display at the Book-Cadillac Hotel, Detroit, Mich., January 12 to 16, 1942.

The American Society for Testing Materials will hold its 1942 Spring Meeting and Group Meetings of A.S.T.M. Committees in Cleveland during the week of March 2nd. The forty-fifth Annual Meeting will be held at Chalfonte-Haddon Hall, Atlantic City, N. J., during the week of June 22nd.

AIRCRAFT WELDING STANDARDS

The Board of Directors of the SOCIETY has authorized the appointment of a committee to develop standards governing welding applications in the aircraft industry. It is believed that such standardization will materially speed up aircraft production in the United States. Moreover, such standardization will result in improved product. It will raise the level of quality of work of sub-contractors and give them acceptable procedures.

At first, the work will be concentrated on resistance welding standards in the aircraft industry. To speed up this work an office has been opened at 850 Euclid Avenue, Cleveland, Ohio. Mr. G. S. Mikhalapov, an outstanding engineer in the field and chairman of the Sub-committee on Resistance Welding Research of the Welding Research Committee, has been loaned to the SOCIETY by the Taylor-Winfield Corporation. Funds have been advanced by the SOCIETY and the Resistance Welder Manufacturers Association.

The National Aircraft Standards Committee has approved of these activities of the SOCIETY, and industry will undoubtedly financially support the work. These activities also have the official approval of OPM (Office of Production Management).

CHARLES WATSON SIDNEY
Consultant

•

RESISTANCE WELDING
INDUCTION HEATING
WELDING POWER SYSTEMS

•

8 Woodcroft Rd. Summit, N. J.

JUST PUBLISHED!

Specifications for Welded Highway and Railway Bridges—Design, Construction and Repair. Third Edition, August 1941.

A completely revised edition of this standard specification for welding of bridges, including appendices on welding symbols, definitions of welding terms and methods for qualifying welding procedures and operators. Prepared by the A. W. S. Conference Committee on Welded Bridges. Board cover, 108 pages, indexed. Price: members, $1.00; non-members $0.75.

Orders for the above publication should be accompanied by check, money order or cash and addressed to AMERICAN WELDING SOCIETY, 33 West 39th Street, New York, N. Y.

OTTO W. WINTER

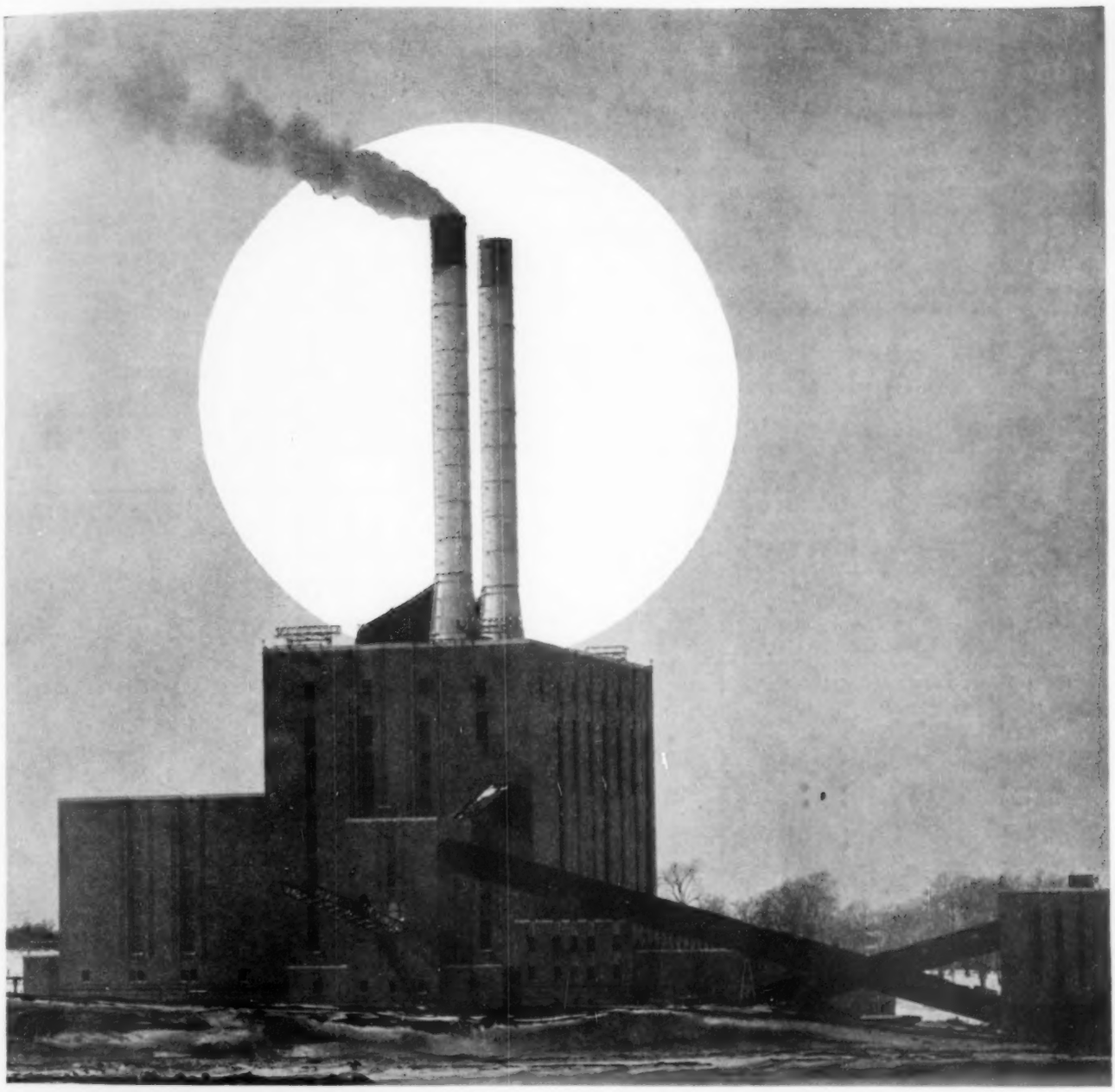
On October 1st, Otto W. Winter assumed the duties of Vice-President in Charge of Manufacturing of the Republic Drill and Tool Co. of Chicago, newly organized manufacturers of high-speed twist drills, employing about 300 workers at this time. Mr. Winter has also been elected a member of the Board of Directors of the Republic Company.

Otto W. Winter

For the past four years, Mr. Winter served as factory manager of the Columbus McKinnon Chain Corp. and its subsidiary, Chisholm Moore Hoist Corp., Tonawanda, N. Y. Other previous positions include the Kent-Owens Machine Co., Toledo, Ohio, as industrial engineer; Whitman and Barnes, Inc., Detroit, Mich., as general manager of the Cutter Division; Cincinnati Milling Machine and Cincinnati Grinders, Inc., as sales engineer and a period in the U. S. S. R. as a consultant to the Soviet Machine Tool and Cutting Tool Trusts.

Mr. Winter is first Vice-President of the American Society of Tool Engineers, national chairman of that society's Emergency Defense Training Committee and a member of the Educational Committee.

He is also a member of the American Society for Metals, AMERICAN WELDING SOCIETY, Society of American Military Engineers and American Society of Safety Engineers. Mr. Winter's moving necessitates his resignation as President of the Rotary Club of the Tonawandas, first vice-president of the Business and Civic Association of the Tonawandas (Senior Chamber of Commerce) and New York State Chairman of the Industrial Relations Committee of the Junior Chamber of Commerce.



STEEL SMOKE STACKS

. . . . of welded construction

The two smoke stacks on the power house in the above view are of butt welded steel construction. They are 16 ft. in diameter by 200 ft. high. Other welded steel plate structures used at power plants include elevated water tanks for fire protection or boiler feed, flat-bottom tanks for storing oil or water, large diameter cooling water pipe lines, bins and hoppers.

CHICAGO BRIDGE & IRON COMPANY

Chicago.....2455 McCormick Bldg.	Birmingham.....1507 North 50th Street	Philadelphia.....1668-1700 Walnut Street
New York.....3398—165 Broadway	Tulsa.....1654 Hunt Bldg.	Boston.....1565 Consolidated Gas Bldg.
Cleveland.....2282 Builders Exchange	Houston.....5621 Clinton Drive	San Francisco.....1097 Rialto Bldg.
Washington.....811 Washington Bldg.	Detroit.....1556 Lafayette Bldg.	Los Angeles.....1471 Wm. Fox Bldg.

Fabricating plants in CHICAGO, BIRMINGHAM and GREENVILLE, PA.

COMFORT AVERY ADAMS—1940 LAMME MEDALIST*

The purpose of giving any one a medal is to focus public attention on the recipient, so that his achievements may gain greater public appreciation, and young men may be inspired to emulate them. During the quarter of a century I have known Professor Adams, his qualities of mind and attitude toward life have been to me a continual source of inspiration, so it is of them that I wish to speak today. He has first and foremost been a teacher—not merely of his students, but of his associates.

There are two ways of learning, of teaching, or of doing—the superficial way and the fundamental way. The first way is the most impressive. I remember well a professor who could answer almost any question immediately. If, however, he were asked a second question, going deeper into the subject, and then a third and a fourth, his answers became slower and less sure, until finally he could give no further information. His knowledge was only about six layers deep.

Professor Adams has always personified the other method to me. When you ask him a question, you will often find him slow to answer, and not very positive about his facts. Then ask him a second question, leading on from the first. He becomes more interested, and replies more fully, though slowly. After the fourth or fifth question, he is fully aroused, has formulated a plan of attack on the problem, and begins to reply more quickly. Still later, he will anticipate your next question, and will develop the possible alternatives. You feel that he creates knowledge as he goes along, and that he is equally at home in all fields of engineering. It is this faculty of reasoning things out on the basis of fundamental principles that has made Comfort Adams a great educator and a great engineer.

Applied to education, this faculty has led him to give his students facts about materials on the one hand, and a few basic physical laws on the other, and then to practice them in applying these laws to a great variety of problems. He was one of the first to use dimensional theory to teach that sense of proportion so essential to designers. I still have a vivid recollection of sitting in the back of the room one Spring day listening to Professor Adams lecture on induction motors, and thinking that the subject being presented was too simple to require my attention. I also remember how on later essaying to reconstruct the theory I decided it was the lecturer rather than the subject that was easy to understand.

Applied to design, this same faculty of fundamental thinking has given Professor Adams an uncanny ability to solve the most abstruse problems by splitting them into a few simple questions which can be treated independently on the basis of known facts. His art in this respect reminds one of the skill of a magician, who undoes the most complicated knots with no apparent effort. His classic papers on induction motor design, and on synchronous machines, marked important advances in the art, and the number of important machines to the design of which he has contributed is legion.

Applied to pioneer developmental work, this faculty is again the key to much that he has accomplished. It has given him a clear insight into what new machines or processes were required for a given purpose, and what facts must be experimentally established to permit their design. In this field, especially, he has unique ability, possessing a rare combination of knowledge of what is practical, disregard of tradition, and determination to carry through despite obstacles.

Just 50 years ago, he became an instructor at Harvard University, one year after his graduation from Case School of Applied Science. Ever since, he has been pioneering in new methods of designing, building and teaching, and all that time he has been sought after by people with problems to solve.

Looked at in retrospect, his distinguished career is seen to have resulted naturally from his pre-eminence in the old-fashioned virtues of clear thinking, persistence and absolute reliability. He has devoted his life to the advancement of engineering, by unselfish aid to students and fellow engineers, as well as by his own inventions. In so doing, Doctor Adams has earned a lasting place in the hall of fame of American engineers, and he has also made a host of friends, who will ever value the inspiration he has given them.

* From an address presented at the annual meeting of the A. I. E. E. during the summer convention, Toronto, Ontario, Can., June 17, 1941.

By P. Alger, Staff assistant to the vice-president in charge of engineering of the General Electric Company, Schenectady, N. Y.

PROGRAM
LADIES ENTERTAINMENT
NATIONAL METAL CONGRESS

Ladies Headquarters—Blue Room, First Floor
Bellevue-Stratford Hotel

MONDAY, OCT. 20

9:00 A.M. Registration at Bellevue Stratford.

12:30 P.M. Luncheon, Terrace Room, Benjamin Franklin Hotel.

2:00 P.M. Sightseeing tour covering historical, business, and residential sections.
(With stop at Independence Hall to see the Liberty Bell, Declaration Chamber and historical relics.)

TUESDAY, OCT. 21

1:00 P.M. Luncheon—John Wanamaker's.

2:30 P.M. John Wanamaker's famous fashion show.
(Special section reserved for ladies of the Congress.)

WEDNESDAY, OCT. 22

11:00 A.M. Leave for Concord Country Club for luncheon. Then continue journey to duPont Longwood Gardens, where special arrangements have been made for display of the fountain and organ recital.

THURSDAY, OCT. 23

1:00 P.M. Visit to Valley Forge through St. Charles Seminary, Wynnewood, Ardmore, Haverford, passing Haverford College and School, Bryn Mawr, Rosemont, St. Davids, Wayne, Stratford and Devon. Stops will be made at Washington's Headquarters, Washington Memorial Chapel, and other points of interest on this historical trip.

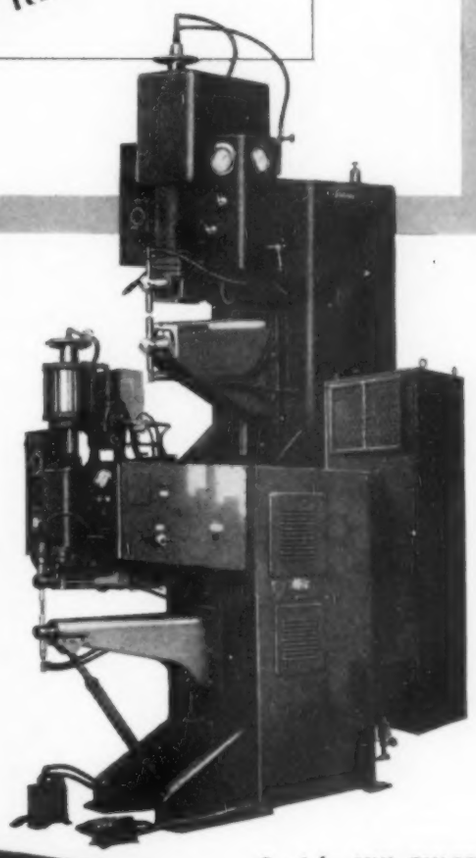
FRIDAY, OCT. 24

No activities have been planned for Friday, but for those who wish, arrangements will be made to visit the Franklin Institute to attend the showing—promptly at 3:00 P.M.—in the Planetarium on "How the Earth Moves." Buses will leave the hotel at 2:30 P.M.

ALWAYS CONSIDER RESISTANCE WELDING

DEFENSE INDUSTRIES
GEARED TO MEET
DOUBLE DEMAND
COMMERCIAL RESEARCH

INCREASED engineering and production facilities enable Federal to handle National Defense orders and maintain commercial research. Federal production is geared to meet service demands . . . whether it's a newly developed Uni-Pulse Roller Spot Welder used by the aircraft industry, or rugged, modernly designed, conventional machines for commercial applications. If you have a metal fabricating problem, consider resistance welding. There is a standard or special Federal machine to do the job.



Send for UNI-PULSE
Technical Bulletin 527

THE Federal MACHINE AND WELDER COMPANY WARREN, OHIO

SALES OFFICES IN ALL PRINCIPAL CITIES

FLEXARC A-C WELDERS

Flexarc a-c welders for every type of welding job ranging from light gage sheet to sustained, heavy-duty industrial fabrication are described in a new 8-page bulletin announced by Westinghouse Electric and Manufacturing Company. Current ranges of these welders are from 20 to 625 amperes.

A copy of bulletin B-2285 may be secured from department 7-N-20, Westinghouse Electric and Manufacturing Company, East Pittsburgh, Pennsylvania.

WELDED STACK BASE

Welded stack base on its way to erection site of a new 150-ton furnace at Open Hearth No. 3 at Bethlehem Steel Company's Bethlehem Plant, Bethlehem, Pa. Remainder of stack which is to be 175 ft. in height will be of riveted construction. The section which is 26 ft 6 in. in

length has an outside diameter of 12 ft at the base and tapers to 9 ft 11 in. diameter at the point it will be connected with riveted construction. Outside diameter of lip at base 13 ft 9 in., weight 28,500 lb.

PICTORIAL BOOKLET

A new pictorial booklet, "You and Your Job in Arc Welding," has just been published by the Hobart Trade School, Inc., Troy, Ohio. The functions and courses of study pursued at the school are explained in this 12-page publication which may be obtained free of charge by writing the Registrar of the school.

WELDING ELECTRODES

A revised, 20-page handbook of welding electrodes and accessories may be obtained free of charge by writing Hobart Brothers Company, Box EW-79, Troy, Ohio.

BATTELLE PUBLICATIONS

More than five hundred Battelle-written books, patents and journal contributions are listed in a new booklet issued by Battelle Memorial Institute, Columbus, Ohio, one of the country's largest industrial research organizations.

Since its beginning, Battelle has utilized the medium of the various technical and scientific journals in disseminating the results of its research in chemistry, ceramics, fuels and metallurgy. Compiled by Thelma R. Reinberg, Institute librarian, the new booklet lists all contributions to the technological literature made by Battelle staff members during the eleven-year history of the Institute. Copies of the booklet are available upon request.

WELDING SYSTEM

A constant potential d.c. welding system for supplying welding energy to multiple arc circuits is described in a new eight-page booklet announced by Westinghouse Electric and Manufacturing Company.

Motor-generators with ratings from 750 to 1500 amperes to meet welding system requirements are discussed with a note on parallel operation. Mechanical parts, controls and motor starting equipment are described. A typical wiring diagram shows electrical arrangement of principal parts in the system.

Distinctive features and prices are listed for the stationary and semi-portable units and accessories.

A copy of catalog section 26-200 may be secured from Department 7-N-20, Westinghouse Electric and Manufacturing Company.

AIRCRAFT REPAIR

Symbolic of another victory—that of American Industry meeting unprecedented demands for National Defense—is the arc welder photographed (below) at La Guardia Airport, main New York field of all plane lines.

Used here to effect speedy emergency repairs to an airplane shock absorber, modern arc welding enables plane manu-

Courtesy Lincoln Electric Co.

facturers, ship builders, tank, gun and armament producers to turn out their vitally needed products at speeds undreamed of in World War I. Today, indispensable for victory, welding is the key process of Production for National Defense.

"CAT FRAME"

Arc welding saved $1953 for the Utah Construction Company on the repair of a broken "cat frame" of cast steel on a two and one-half yard shovel. The huge casting, weighing over five tons, broke just back of the drive sprocket end.

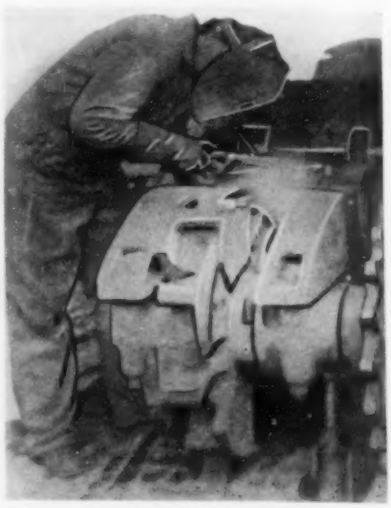


Photo courtesy Hobart Brothers Company

First, the track was "broken" and the front track idling sprockets disassembled in order to get to the broken frame. Hydraulic jacks were used to raise the frame back to place and to align it. Then, the frame was tack welded into position. The crack was veed out and welded with high-tensile and mild steel electrodes. Next, two pieces of high-tensile steel straps $^3/_4$ x 6 x 28 in. were welded to the frame as reinforcements. These straps were welded to the frame in the form of a gusset in order to strengthen the frame near the break.

L. E. Ridnour, welding foreman of the project, reported that the shovel was back at work twelve hours after the breakdown. A new "cat frame" would have cost the construction company $2000 plus freight. The welding repair job cost the company $47.46.

TRAINING EMPLOYEES

A program of cooperation with American industry to train promising young employees as engineers has been announced today by Dean S. C. Hollister of the College of Engineering, Cornell University. The plan will use part of the income from the $2,000,000 John McMullen Scholarship Fund to create John McMullen Industrial Scholarships for apprentices in industry selected by officers of the companies as men whose value would be increased by a college education in engineering.

Enthusiastic endorsement of the program has been given by numerous leaders of the industry, following the successful experiment worked out with the General Electric Company during the past year. Last September two high-school graduates from the four-year G. E. apprentice train-

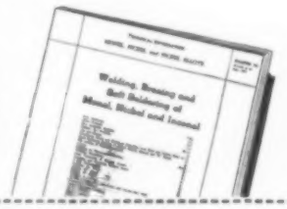
RECRUITING NEW MEN?

Then give each one a copy of this useful manual

Years of experience have taught your older hands a lot about welding INCO Nickel Alloys. They know how to make good sound welds in Monel, Inconel, pure Nickel, and the clad metals.

Mostly then for the benefit of the newer men, we suggest that you keep on hand a good supply of INCO Bulletin T-2, "Welding, Brazing, and Soft Soldering of Monel, Nickel and Inconel." This booklet gives detailed instructions on all joining processes, also on jigs and clamps, welding wires and fluxes, cleaning, heat-treating. In addition, it contains thoroughly practical information on a raft of other subjects.

In sending for these bulletins, don't think *only* of new men. Old-timers, too, should keep a copy for reference. Use the attached coupon to make your requirements known. We'll respond promptly... no obligation, of course. The International Nickel Company, Inc., 67 Wall St., New York, N. Y.



THE INTERNATIONAL NICKEL COMPANY, INC.
67 Wall Street, New York, N.Y.

Gentlemen:

Please send without charge or obligation_____copies of Bulletin T-2 "Welding, Brazing, and Soft Soldering of Monel, Nickel and Inconel."

*Name*_____ *Title*_____

*Company*_____

W.J.-10-41

*Address*_____

ing course were awarded McMullen Scholarships of $400 a year, paying full tuition during the four- or five-year courses they chose to pursue. Both have made excellent records in the College of Engineering.

The Cornell Board of Trustees has now authorized the award of four such scholarships each year, making an eventual total of at least 16. The number may be further increased. Scholarship holders must be high-school graduates qualified to meet the regular entrance requirements of the college, must have served some time as workers in industry, preferably in a regular training course, and must be recommended by their employers as men of special ability whose careers would be helped by a college course in civil, electrical, mechanical or chemical engineering. It is contemplated that the McMullen Industrial scholars will return to the same organization by which they were previously employed.

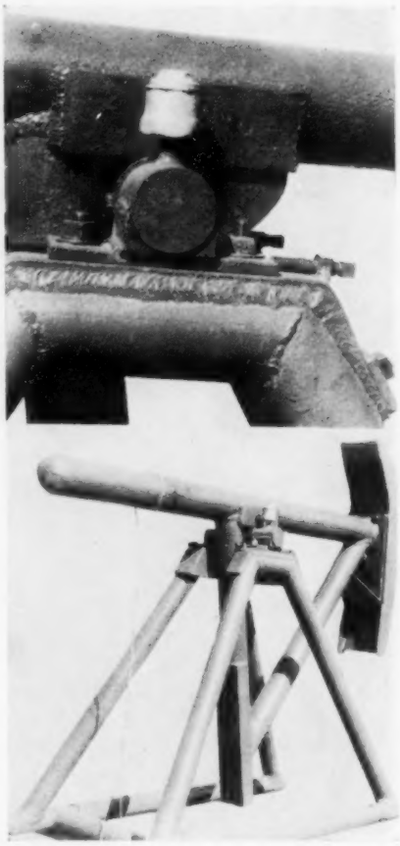
ARC-WELDING COST BOOKLET

Cost of arc-welding electrodes can now be estimated rapidly for welding any type of joint on any thickness with either bare or coated electrodes by the use of the new Airco *Electrode Consumption Calculator*. Just published by Air Reduction, this helpful booklet tells how many pounds of electrodes are required per linear foot of weld. The calculator includes consumption figures for both bare and shielded arc electrodes on all metal thicknesses commonly employed in making fillet welds, square groove butt joints, V and U groove butt joints, bevel grooves and J grooves. The amount of steel deposited per linear foot of weld is also shown. As a further aid on other joints not shown, the basic formulas used in these calculations are included.

Copies of the new Airco *Electrode Consumption Calculator* can be obtained by writing to Air Reduction, 60 East 42nd St., New York, N. Y.

DRILLING EQUIPMENT

Special drilling equipment is difficult to secure promptly while manufacturers are rushed with defense work. Small welding shops are helping to relieve the problem by building drilling equipment to meet the specific needs of local customers. Pictured here by courtesy of Hobart Brothers Company, Troy, Ohio, is a pump jack constructed from used pipe by R. E. Fillmore, job welder, of Augusta, Kansas. Features of this originally designed pump jack are adjustable mule heads made from a used brake band; replaceable beam pin (most jacks have pin welded to beam); automatic bearing oilers. Steel bearing (inset photo) was constructed from angle iron welded to pipe. Standard size brass bushings were pressed inside the bearing pipes and capped with a cast-iron plug. Walking beam was constructed in a similar manner by welding angle iron to the beam, then fish



plating and sleeving the under side so that the pin would be held solid to the beam and work in the bearing on both sides. These pump jacks require very little servicing and are very inexpensive to construct.

DESIGN OF MODERN STEEL STRUCTURES

By Linton E. Grinter, Ph.D., C.E.

This book on the Design of Modern Steel Structures forms a companion to Vol. 1 of the Theory of Modern Steel Structures. Taken together they are intended to cover all of the problems of analysis and design that can be treated to advantage in the usual undergraduate courses in statically determinate structures.

There is considerable emphasis in this volume upon the design of structural members and structural joints both in steel and timber.

Connections are studied first in the order of rivets, welds, pins and timber connectors. The study of complete structures, includes the design of riveted and welded girders and roof trusses, a low-truss highway bridge, and a tall building frame.

The specifications used and given are those of the American Institute of Steel Construction (AISC), American Railway Engineering Association (AREA), American Association of State Highway Officials (AASHO), and AMERICAN WELDING SOCIETY (AWS). These specifications control a large part of all structural design work for buildings and bridges.

The author hopes that this book may serve to help produce young engineers having a thorough background of elementary structural design. Such men may find an immediate position in engineering or they may prefer to develop a more scientific point of view by study for an advanced degree.

Published by the Macmillan Company, 60 Fifth Ave., New York, N. Y. 452 pages. Price $5.00

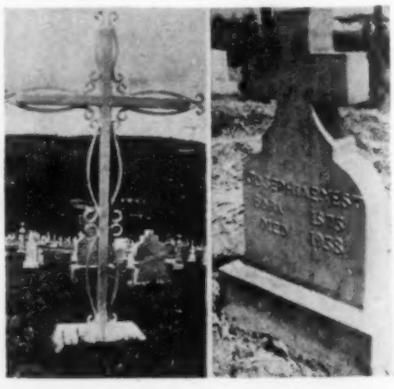
HOBART MONTHLY ARC-WELDING NEWS CONTEST

Cash prizes totaling $200 or more every month are being offered for interesting news items about arc-welding applications in a contest being sponsored by Hobart Brothers, Troy, Ohio. A first prize of $100, second of $50, third of $25, fourth of $15 and fifth of $10 are distributed every month. Additional special awards from $1 to $10 are awarded entries deemed worthy of purchase by contest judges. No lengthy essay or technical data are required of contest entrants.

Official entry blanks and contest rules may be obtained by writing the Contest Manager, Hobart Brothers Company, Troy, Ohio.

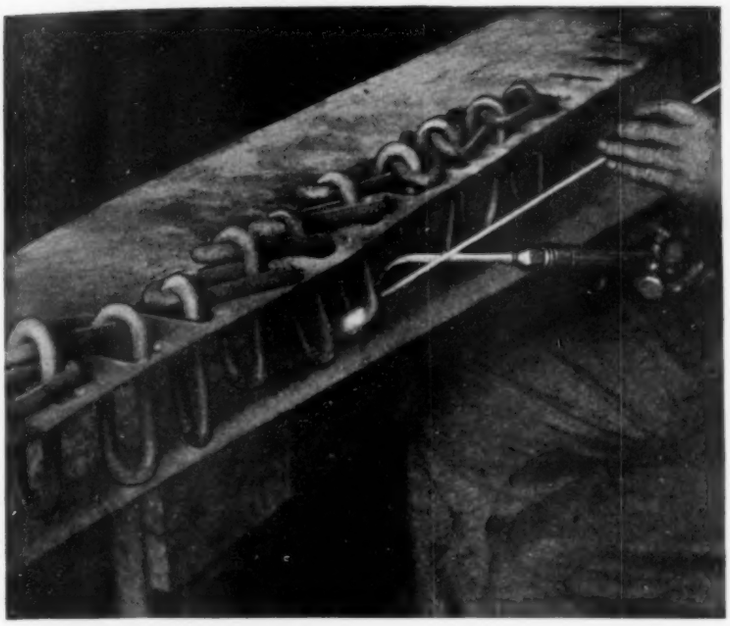
WELDED MEMORIALS

Pictured below through courtesy of Hobart Brothers Company, Troy, Ohio, are two attractive grave markers built entirely by arc welding. The marker on the right was built from $^3/_{16}$-in. steel plate cut to shape with an acetylene torch. Welding was done with a $^5/_{32}$-in. rod at 130 amperes. Lettering on the marker was also made by the electric arc. A similar grave marker of stone costs $100—this arc-welded marker, completely finished, sand blasted and metalized costs but $25.00.



A less expensive marker is the grave maker pictured at the left. The cross was made from 2 x 2 x $^3/_{16}$-in. angles welded to form hollow-square tubing; filigree work made from $^1/_2$-in. square iron hammered to shape. This grave marker completely finished and set in concrete base costs only $12.00. Similar markers of stone cost $75.00.

Is Wear Costing You Money?



If so, cut your costs by hard-facing wearing parts

Hard-Faced Conveyor Links Last Longer

THE life of the conveyor chain shown above was increased 2 to 3 times by hard-facing the links with Hascrome self-hardening chromium-manganese-iron rod. Hascrome hard-facing rod gives rebuilt parts a longer life than new parts—at reduced costs.

The simple jig illustrated above makes it easy to apply Hascrome rod to these links. To do this job, every second link is dropped through the slots in the sheet metal rack, and the worn areas are rapidly rebuilt. The chain is then rearranged to expose other link ends, and the hard-facing proceeds until all worn surfaces have been restored.

Practical field engineers of Haynes Stellite Company—and service operators of The Linde Air Products Company—can help you hard-face wearing parts profitably. Write or phone the nearest district office today.

Headquarters for Hard-Facing Materials

HAYNES STELLITE COMPANY

Unit of Union Carbide and Carbon Corporation

New York, N. Y. UCC Kokomo, Indiana

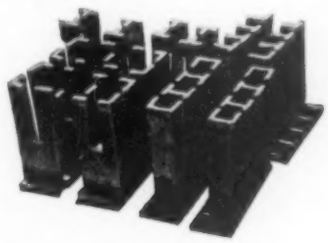
Chicago—Cleveland—Detroit—Houston—Los Angeles—San Francisco—Tulsa

Hard-Facing Hints

VISES—The two vises shown here are used on drill press tables to hold small knitting machine parts. Before hard-facing was adopted, they were frequently

replaced because of severe wear. Now their life has been greatly prolonged by hard-facing with Haynes Stellite No. 1 rod. When they finally begin to show wear, they can be hard-faced again for another long period of service.

TAMPER FEET—These cinder block tamper feet formerly lasted one week, but since the corners were hard-faced by applying Haynes Stellite No. 1 rod,



their life has been increased to eight weeks. It only requires a small amount of Haynes Stellite rod to hard-face these tamper feet and they are thus economically kept at a high operating efficiency.

"Haynes Stellite" and "Hascrome" are registered trade-marks of Haynes Stellite Company.

NEW CYCLOTRON FOR UNIVERSITY OF CALIFORNIA

Being erected high above the football field of the University of California in Berkeley is a new $1,500,000 cyclotron said to be the greatest atom smasher in scientific history.

Of tremendous importance, it will standardize milk with a fixed iron and calcium content. It may also give mankind new power by turning loose the tremendous energy stored within the atom.

Photo courtesy The Lincoln Electric Co.

Constructing the New $1,500,000 Cyclotron for the University of California at Berkeley. Arc-Welded Steel Construction Is Used to Resist Tremendous Forces Which Will Be Turned Loose When the Monstrous Atom Smasher Goes into Action

Into construction of this monstrous scientific structure (see accompanying illustration) go 4900 tons of steel, all of which is welded by the modern shielded arc process. The spectacular use of welding was on 58-foot slabs of steel, 6 feet 3 inches wide and 2 inches thick, weighing 17½ tons. In the foundation are 98 plates 17 feet wide by 75 inches deep.

Not visible in the photo but now approximately 60% completed is one of the giant magnets, each of which will weigh 300 tons. The structure also will contain the world's largest vacuum.

Expected to open new worlds of exploration to the scientist and solve many problems for farmer, consumer and manufacturer, the structure utilizes arc-welded steel to resist the tremendous forces let loose when the unit goes into action.

At least a year will be required to complete construction.

BASTIAN-BLESSING MOVES INTO NEW HOME

The Bastian-Blessing Company of Chicago, noted pioneers and experts in the design and manufacture of the popular Rego oxyacetylene welding and cutting apparatus and of Rego high-pressure gas equipment, has taken another huge stride forward by moving into its new streamlined factory and home office at 4201 Peterson Avenue, on Chicago's northwest side.

The building covers 182,000 square feet on a single floor and has the departments so laid out that materials and operations simply flow without interruption from one end of the building to the other. The

tract embraces 13 acres along a railroad line, and adjoins one of Chicago's finest residential sections.

WATER STORAGE TANK

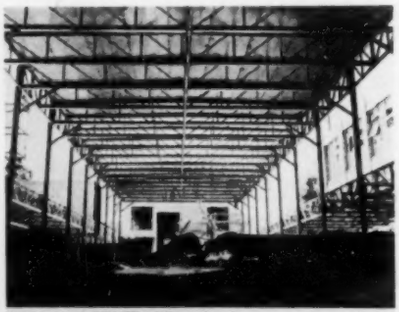
The Pittsburgh-Des Moines Steel Company is contractor on an all-welded three million gallon water storage tank for the city of Houston, Texas. Field construction started early in July at the northeast city plant, and all work exclusive of painting will be completed late this month.

The circular tank is 185 feet in diameter and 20 feet high. Bottom plates were installed using fillet welds on lap joints, and butt joints have been used in wall plates.

The Southwestern Laboratories, Houston, Texas, is handling the welding inspection.

STEEL FABRICATED ON BUILDING SITE

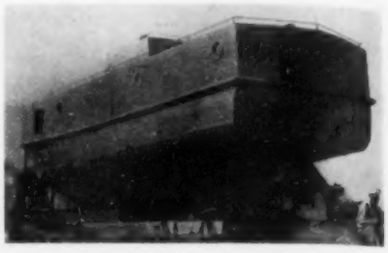
Hobart Brothers, Troy, Ohio, has just completed a completely welded plant addition, 70 by 200 feet. Structural steel was fabricated in an adjoining building and moved a few feet to the building site by crane. "On the job" fabrication elimi-



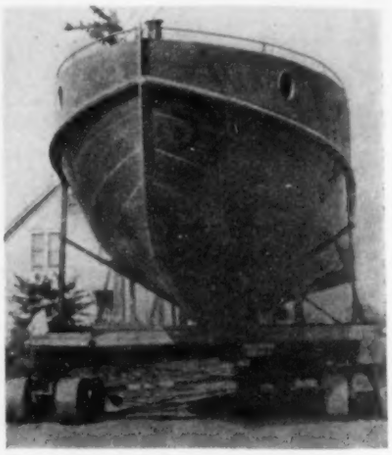
nated delivery delays so that the building was completed in a month and a half.

FISHING BOAT

The forty-seven foot all-welded steel fishing boat, pictured through courtesy Hobart Brothers Company, Troy, Ohio, appears quite shipshape after seven years



of heavy commercial fishing by Vernon Ostrander of Waukegan, Illinois. The only upkeep on this boat has been a paint-



ing once each year. Plates up to the water line were ¼ inch; 3/16-inch plates up to the deck; deck and deck house of 12 gage steel.

WELDED CUTTER

This trim forty-two foot cutter was constructed entirely by arc welding without use of a single rivet in any part by the Dunn Coach & Body Works of Detroit, Michigan. Despite the fact that only three men were on the job and that no power machinery was used, with the exception of a 300-ampere arc welder, only ninety-three days elapsed from the time the keel was laid until the last plate was welded into place.

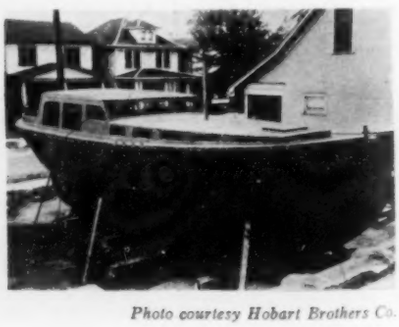


Photo courtesy Hobart Brothers Co.

BUILT-IN power savings ...IN THIS HEAVY-CURRENT A-C WELDER!

Put this husky A-C welder on the heaviest welding job you've got... get the faster welding with heavier electrodes that a-c freedom from arc blow enables you to get . . . *without* fear of penalties or premiums in current costs because of low power factor!

Westinghouse Flexarc A-C Welders with built-in power-factor correction give you lowest welding costs—*plus* the a-c advantages of low initial cost, absence of magnetic arc blow and smooth, spatter-free welds. Single pre-set dial provides infinite number of current settings, allows setting to be changed under load. Two capacities, 500 and 300 amperes (illustrated) provide welders suited to any heavy current service. Investigate Flexarc's exclusive features before you buy—write for booklet B-2285! Westinghouse Electric & Mfg. Co., East Pittsburgh, Pa., Dept. 7-N.

300-AMPERE RATING
60 to 375 amp. range
(illustrated)

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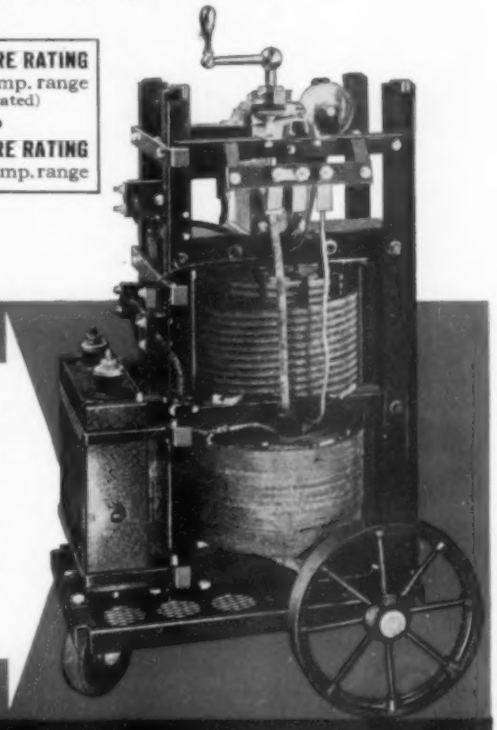
500-AMPERE RATING
100 to 625 amp. range



- **MOVABLE CORE, STATIONARY COILS.** No flexing on power cables, no movement of current-carrying parts. Reduced wear means lower maintenance costs!
- **SEGREGATED REACTANCE**—permits use of finely stranded, low loss cable. Reduces eddy current losses.
- **HIGH POWER FACTOR.** Built-in capacitor gives lowest kv-a input, highest efficiency and lowest welding cost.
- **AMPLE COPPER AND IRON**—permits ventilation by natural convection, prevents loss of efficiency through "overworking" these parts.

J-70344

Westinghouse

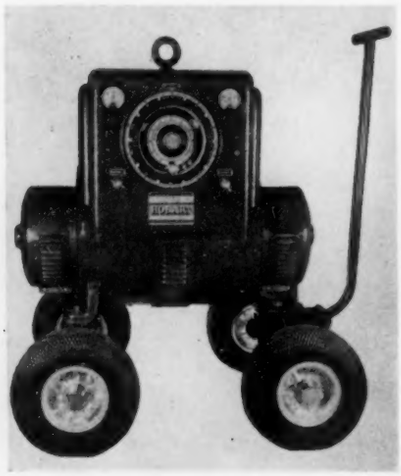
FLEXARC WELDERS

NEW PRODUCTS

The Society assumes no responsibility for the validity of claims in this Section

TRAILER WELDER

A new four-wheeled light-weight pneumatic-tired trailer for mounting all Hobart electric drive welders is announced by Hobart Brothers Company, manufacturers of arc-welding equipment, Troy, Ohio. Easy portability makes this new welder doubly useful enabling it to make hurry-up trips to different parts of the plant and yard for emergency production, maintenance and repair work.



The trailer is designed so that the mounting is easily accomplished by means of four bolts in the frame of the trailer which register with four holes in the legs of the welding machine. Unit is easily moved by hand by virtue of the low, underslung construction, narrow 27-in. tread and method of balancing. Trailer is of arc-welded steel construction throughout.

This unit weighs 120 lb.; measures 12⅞ in. high; 45 in. over-all height; 44 in. over-all width; 33 in. from hub to hub; 25% tilting angle; 14 in. jumbo four-ply tires.

3000-LB. CAPACITY WELDING POSITIONER

An improved heavy-duty 3000-lb. capacity welding positioner was recently made available by the Industrial Division, Ransome Concrete Machinery Company, Dunellen, New Jersey. This machine rounds out Ransome's line of positioners with capacities from 2500 lb. hand-operated to 8 ton heavy duty motor-operated.

The newly designed positioner has a 40-in. square machined steel table-top provided with 4 radial and 4 longitudinal T-slots to take ¾-in. bolts making for quick and easy set-up of pieces to be welded.

The all-welded construction of the unit assures safety to the operator when working under full load conditions. A 3000-lb. load with a center of gravity 12 in. above table and 12 in. eccentric from center of table may be carried. A tilting motor tilts the table from horizontal to 45° beyond vertical. Table top may be rotated at constant speed or variable speed as desired. Remote push button controls for the convenience of the operator are supplied.

Literature and complete details may be had by addressing the Company.

---

180 SHELL CASES PER HOUR

Cases for transporting loaded 25-lb. shell, ready for firing, are now being assembly welded in at least one plant on a Progressive Hydromatic welder, at a rate of 180 complete cases per hour. With 24 welds per case, the machine is thus producing 4320 welds per hour. Assembly specifications call for unusually close tolerances for this type of work, to hold the shell securely and permit stacking of cases for transportation.

Designed by Progressive Welder Company, 3100 E. Outer Drive, Detroit, the Hydromatic is equipped with power-clamping fixture to facilitate loading and unloading. The parts for the case are dropped over and into the locating fixture which also forms one of the electrodes. A lever is pulled down and plates come against the work under power, clamping the parts securely in the fixture and against the inner electrodes. The 24 welding gun units then move in against the work, and the welding cycle starts. On completion of the welds, the points move away from the work, the clamps are retracted by reversing the lever, and the assembled case is removed.

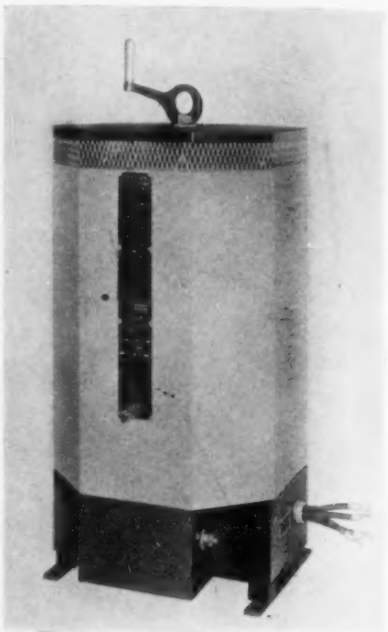
Operation is completely automatic from the moment the clamping action is started, until the case is ready for removal.

The welding units, power assembly and guns are all of standard design as in other Progressive Hydromatics, only the fixture and base being of special construction.

TRANSFORMER ARC WELDERS

A new line of A.C. Transformer Welders in 300, 500, 750 and 1000-ampere capacities has just been announced by Wilson Welder and Metals Company, Inc., 60 East 42nd Street, New York, N. Y.

Known as Model TW, these welders are completely self-contained units that will meet the heavy arc-welding needs of shipyards, railroads and steel mills. For 220, 440 or 550 volts, 25 or 60-cycle current. When arranged for 220 and 440-volt operation, single phase, either voltage can be brought into use by a reconnection of the leads which are brought outside the unit.



The new welders have a wide range of current output, and continuous stepless current regulation is provided over the entire range by means of a hand crank on top of the machine. This crank makes it possible to rapidly shift the setting as changes are made from one class of work to another.

The Model TW conforms to N. E. M. A. requirements, and is said to operate cooler and therefore last longer, because of divided construction of the coils which allows greater surface area to be exposed to the cooling air. All coil covering is spun glass fiber, heat-resistant, Class BB insulation, providing trouble-free operation even if used continuously at maximum settings.

X-RAY INSPECTION
FOR HEAVY INDUSTRY

● KELEKET Super-Ray Industrial Unit installed in the plant of H. G. Vogt, Louisville, Ky.

--now made practical and profitable by KELEKET!

THE increasingly rigid standards for materials in the metal industry have made inspection by X-ray a necessity.

This demand has been greatly accelerated by the defense program, where flawless welds and castings are vital both for speed in production and safety in use.

KELEKET X-ray inspection units are the answer to these new demands. The installation illustrated is one of the powerful units for the examination of heavy metals. KELEKET'S line is complete, with a range of power to meet every need of industry — as standard equipment or engineered to the job.

These X-ray units were among the first accepted by industry and are favored by leading manufacturers using this modern method of inspection. This is because of KELEKET'S experience of more than forty years in designing and building X-ray apparatus.

Our engineers are at the service of management for advice on how X-ray inspection can be profitably and practically adapted for any industrial purpose. Mail the coupon for more detailed information.

THE KELLEY-KOETT MFG. CO., COVINGTON, KY.

Representatives in 64 Cities

Super-power for rapid inspection of metal over 2½ in. thick.

Easy to operate and control. Shockproof and safe.

Complete unit on wheels shoots heavy machinery where it is!

Flexibility provided by angulating tube head.

Completely self-contained unit can be mounted to meet your requirements.

KELEKET X-RAY

The Kelley-Koett Mfg. Co.
218 West Fourth Street,
Covington, Ky.
● Without obligation, please advise me how Keleket Equipment can be used profitably in this plant for inspection of

Name _____ Title _____
Firm Name _____
Address _____ State _____
City _____

PIONEER CREATORS OF *QUALITY X-RAY* EQUIPMENT SINCE 1900

On 60-cycle units, all sizes are fan cooled except the 300-ampere size, which is cooled by natural draft. On 25-cycle units, all sizes are fan cooled. The 60-cycle units have high and low range switches, while the 25-cycle units have only one range. This low range switch provides current adjustments on the 500-ampere size from 40 to 650 amperes. Power factor correction is included in all models for 60-cycle operation except the 300-ampere size. Welders built for 25-cycle operation do not have power factor corrected. Efficiency of all the TW units is approximately 80 to 85%.

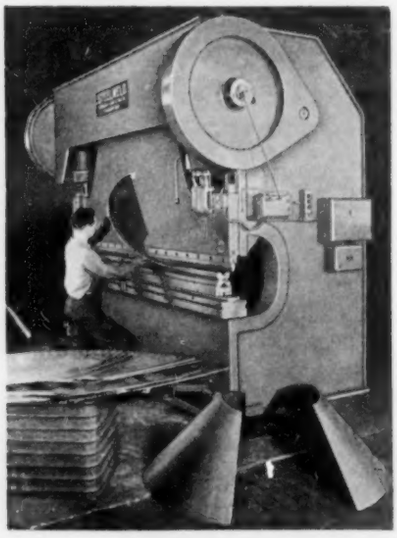
Further information or descriptive literature on these new Transformer Arc Welders may be obtained by writing the Wilson Welder and Metals Company, Inc., 60 East 42nd Street, New York, N. Y.

RAM-TAPERING MECHANISM

The complete line of bending presses made by the Steelweld Machinery Division of The Cleveland Crane & Engineering Company, Wickliffe, Ohio, is now being furnished with a ram-tapering mechanism that makes possible a new field of applications.

The tapering mechanism enables making conical sections as illustrated, without the use of special dies. The work can now be done with standard bending dies.

Tapering the ram is extremely simple. It is only necessary to operate the ram-tapering lever (long lever with ball handle

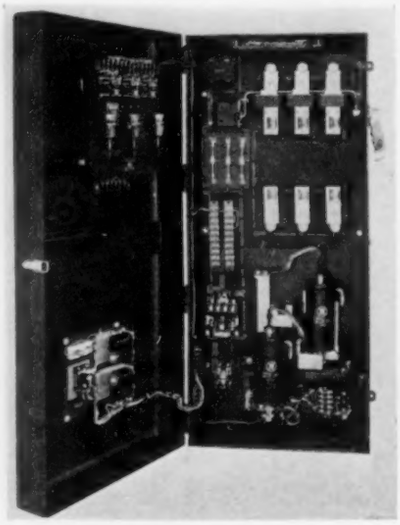


clearly visible in front of ram) which disengages the ram clutch. This permits operation of the right-hand ram screw only, which raises or lowers the right end of the ram, thus producing tapering. Either end of the ram can be tapered as much as one-quarter inch per foot length of bed. There are no bolts to loosen or tighten. The ram swivels on trunions in the slides so there is no cramping on guides or bearings.

The press illustrated is shown working steel $^{3}/_{16}$ in. thick. Two of the sections being formed make the bottom of a 48-in. diameter bucket. This particular machine is a Steelweld Bending Press Model 14–10. It will handle plate 10 ft. by $^{5}/_{16}$ in. between housings and 12 ft. by $^{1}/_{4}$ in. over entire length of bed and ram.

POWER AND CONTROL UNITS

Complete power and control units for resistance welding—including, in one compact cabinet, contactors and firing relays, sequence timer, protecting fuses, limit switches, motor starter, low voltage trans-



former and relay, etc.—are now available from Weltronic Corporation, Detroit.

The complete power cabinets eliminate not only the necessity for the usual multiplicity of separate control units but also eliminate all external inter-unit wiring requirements, so that only the simplest of wiring is required to connect the complete set of controls to the machine, while simple three-wire connections are made to the 440- or 220-volt power supply circuit.

Similar units—without ignitron contactors and firing relays—are available for controlling operation of a wide variety of automatic machines.

NEW REGALVANIZING RUSTPROOFING PROCESS AND MATERIAL

With U. S. Patent 2,224,953 granted and others pending, Galv-Weld, Inc., is making available to the metal fabricating industry its new process which permits the welding of galvanized or other sheets and structural metal parts, regardless of size, so that the joints are left in thoroughly rustproof condition.

In the case of welded joints of galvanized material, regalvanizing is accomplished at the time of welding and no redipping is necessary. It is said that welded products can thus be manufactured from galvanized sheets or shapes, eliminating entirely the present practice of dipping the finished product to rustproof it. Where the product is of such size that it cannot be dipped, the advantage is obvious. The process and materials are adaptable to all types of welding.

National distribution of Galv-Weld materials to licensed users of the patented process is assured through the sales organization and distributors of the Metallic Products Division of The Eagle-Picher Lead Company of Cincinnati, and immediate deliveries can be made. Galv-Weld, Inc., Mutual Home Building, Dayton, Ohio, offers a brochure to those interested in investigating its process. License forms are included in this booklet.

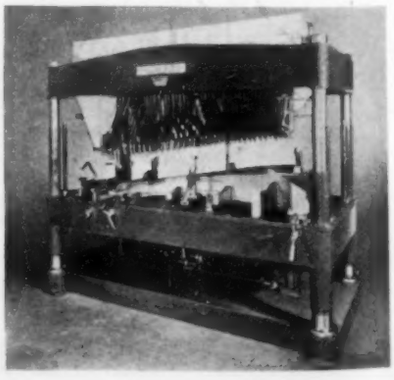
The process has been used successfully by its developers for over four years on light and heavy galvanized angle iron frames, many of which have been subjected to all types of extreme weather conditions, but is now being offered for license for the first time.

It has been found by actual practice that structural shapes or sheets can be welded together and then by utilizing the stored up heat in the welded sections, the welded joints can be galvanized or regalvanized.

The process consists, in its barest essentials, of rubbing over the bare spots, which have been heated by the welding, a stick of low-melting galvanizing material to form thereon a smooth coating of metal which will have all of the corrosion-resisting properties, as well as the wearing qualities of the original galvanized coating.

ULTRA SPEED WELDER

Thirty-six hundred welds an hour is the job this Ultra-Speed unit, built by Progressive Welder Company, 3100 E. Outer Drive, Detroit, is called upon to perform. The job is to assemble spot weld a wheel housing to a rear quarter panel of an automotive body—frequently a flash-welding operation.



Figuring ELECTRODES?

Use the New WELDERULE

the RIGHT answers in a FEW SECONDS

Ask the Welderule

"How many pounds of electrodes will I need for this job?"

"What will be the total cost of electrodes for this job?"

"What weld footage can I get from my electrodes in stock?"

The answer to these and many other questions are quickly obtainable with the G-E Arc Welderule—a rapid-calculator which further extends G-E engineering service to users of G-E electrodes.

With raw material on a priority basis, no one connected with arc welding can afford to be without accurate knowledge of future stock requirements or production obtainable from present stock. You can keep a current check on the answers to such questions with the Welderule.

There's a G-E arc welding distributor in your locality who will be glad to work with you on your electrode problems. He will also supply you with a Welderule.* Get in touch with him today, or with the nearest G-E office. General Electric, Schenectady, N. Y. Read what these G-E electrode users say!

**Price 25¢ each*

WELDING ENGINEER—"This Welderule helps me to specify the most economical types and sizes of electrodes for various jobs."

WELDING SUPERVISOR—"The Welderule gives me a ready check for comparison of results."

PURCHASING AGENT—"The G-E Welderule helps to simplify our purchasing problems by quickly translating production requirements into pounds of electrodes."

STOCK KEEPER—"The Welderule helps a lot. Now I can tell 'em what they can get out of electrodes on hand."

GENERAL ELECTRIC

673-23-8748

The complete cycle of the unit requires only 40 seconds—including time for loading and unloading the fixture, bringing the points down against the work, and going through the welding cycle, two welds at a time.

HEAT CONTROLS

A complete line of resistance welding heat controls, designed to take care of virtually every conceivable application of such units to resistance welding operations is being offered by Weltronic Corporation, Detroit.

The various models available are designed to take care of such applications as the following:

1. Single-weld operations, using either guns or pedestal type welders.
2. Pulsation welding—requiring different amounts of current for different "shots."
3. Multi-spot welding as with hydromatics, ultra-speed welders, etc., where individual adjustments are desired for each weld or group of welds in the series.

The Weltronic Series 50 line of heat controls consists of three basic models, the 50-Y unit designed for accurate current control for single welds, the 50-W, a multiple heat control designed for either pulsation or multi-spot welding, and the 50-XX which is an automatic heat rise control for either single-spot or pulsation welding.

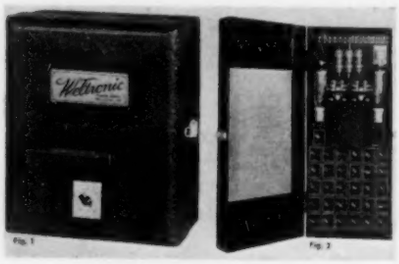


Fig. 1—Weltronic 50-Y Heat Control designed for Repeated Single Welds, with Any Make of Welding Equipment or Timer

Fig. 2—Weltronic Multi-Spot Heat Control for Use with Hydromatic or Ultra-Speed Welders

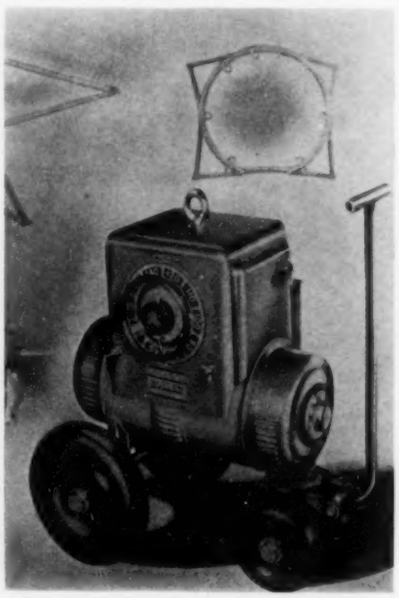
The number of dials provided is independent of the number of individual welds in the machine cycle to be controlled.

In addition there are available a number of other models, such as dual and triple heat controls which are fundamentally combination units designed to take care of accurate pre-selective current adjustment for two or three operations performed with the same machine or gun, etc.

All Weltronic heat controls are of the electronic type, providing an infinitely variable adjustment of current value. Their function, of course, is to "chop out" portions of the current wave to control the amount of current actually used for welding. When such heat controls are provided, auto-transformers may of course be omitted in the welding circuit. The use of electronic heat control implies the requirement, of course, that electronic type of contactors be used in the welding equipment circuit.

AIRCRAFT WELDER

Hobart Brothers Company, Troy, Ohio, has introduced a specially designed arc welder for aircraft construction purposes with the trade name, "Aircraft Special." Although it embodies the same design and operating speed (only 1750 r.p.m.) as other Hobart Multi-Range Arc Welders, it has been modified to give the "quick, hot start" so necessary to success in welding light-gage alloy tubular members in airplane construction. It also provides a lower range of welding current specified from 10 to 150 amperes at normal welding voltage.



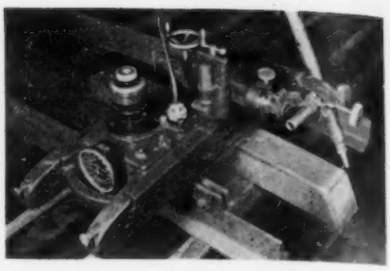
Characteristics of this machine are ideal for the welding of all light-gage metals that are weldable by the electric arc—especially the welding of X-4130 chrome molybdenum steel on aircraft engine mounts.

The "Aircraft Special" welds especially well with coated electrodes of $^{1}/_{32}$-in. to $^{5}/_{32}$-in. size without burning through and with steady progress along the seam due to the "soft arc" that "hangs on" even under low current conditions. Dual control of welding current and open circuit voltage enables the operator to select exactly the right volt-ampere combination for each job. Remote control, standard equipment, makes it possible for the operator to make slight heat adjustments after the "hot start" without return to welding machine.

The new welder is the Hobart Multi-Range type with four laminated main poles and four interpoles. The machine is only $28^{1}/_{2}$ in. high and 17 in. wide (overall measurements for stationary model).

TORCH HOLDER

Extra convenience and accuracy in setting Radiagraph cutting torches for any desired angle of cut is now made possible by the new Protractor Type Torch Holder, just introduced by Air Reduction. As an



example of the type of work for which the accuracy and time-saving features of the new holder are particularly valuable, a bevel cut billet is shown in the photograph. A circular knurled knob permits angular adjustment, as shown on the scale. The new holder which has a 90° angle range can be attached to any standard Airco Radiagraph.

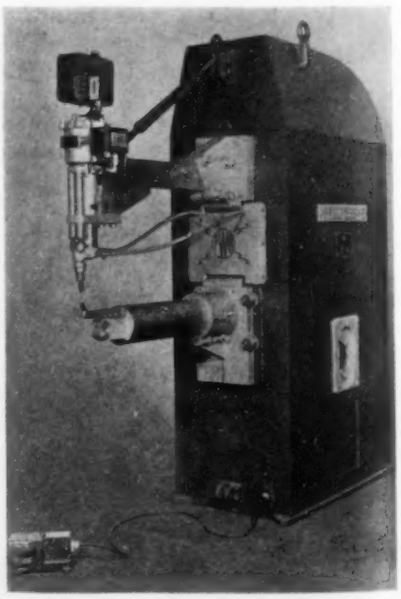
DEEP THROAT WELDER

To facilitate resistance spot welding inside of deep assemblies, such as tanks of various types, barrels, etc., Progressive Welder Company, 3100 E. Outer Drive, Detroit, has introduced a variation of its well-known pedestal welder.

The deep-throat welder, shown in the accompanying illustration, has its lower arm built of heavy tubing and fitted with a replaceable adaptor for the lower electrode. The construction makes unnecessary the supporting of the lower arm by means of the usual braces, due to its inherent rigidity. Elimination of the usual braces, in turn, makes possible sliding deep assemblies over the arm to full throat depth.

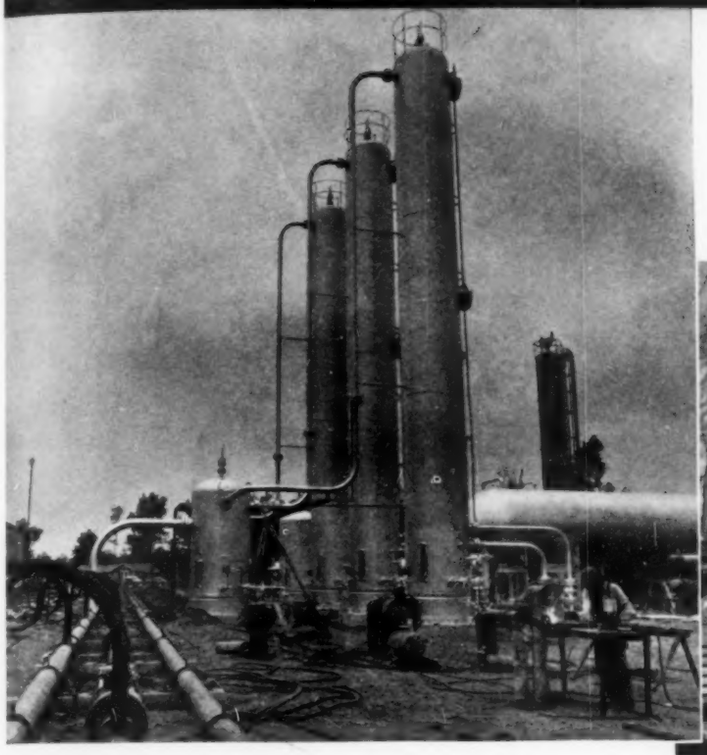
The upper arm, carrying the upper electrode and gun assembly, is braced in the conventional manner. Both upper and lower arms are designed so that they may be adjusted in or out to increase or decrease throat depth as may be required.

To weld a part such as a cylindrical tank, the unit is slipped over the lower arm to desired location for welding, the



COTTON VALLEY

Pierce Governors do their bit on big national defense project!

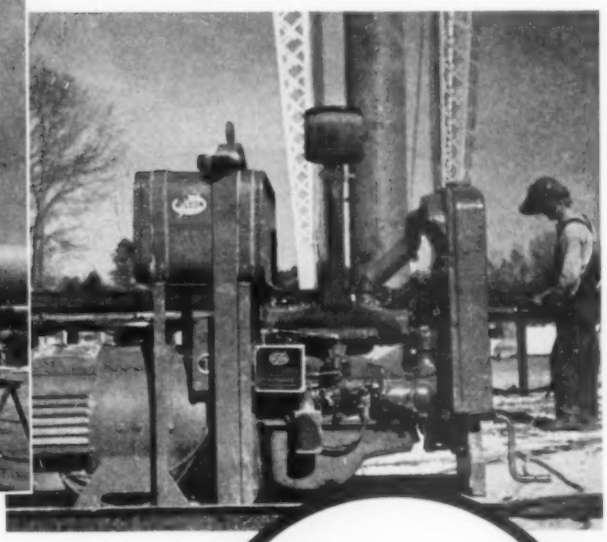


Here's the JOB . . .

One of America's largest and most modern natural gasoline cracking plants, and a mighty big welding contract!

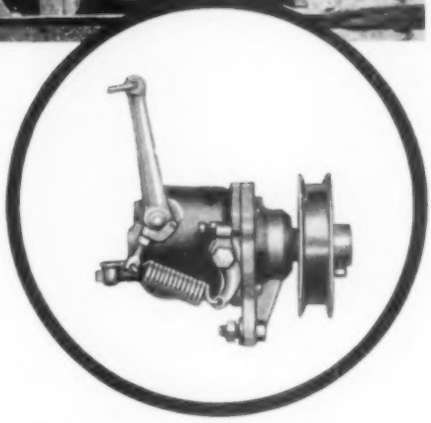
. . . Here's the WELDER

One of the battery of Wilson Arc Welders that speeded the job to completion.



● On the Cotton Valley Project thousands upon thousands of strong, sound, leakproof welds had to be made. Pipe had to be joined quickly, surely, and for keeps. Holding the arc constant . . . weld after weld . . . with split-second recovery after striking arc . . . was the job entrusted to Pierce Governors. When there's a Pierce Governor on your welder you can confidently handle speed-up jobs . . . you're sure of the weld because you're sure of the governor.

Pierce Governors are standard equipment on most engine-driven welders. Write us for advice on efficient governing for better welding.



Here's the GOVERNOR . . .

This dependable Pierce Governor is used on Wilson Arc Welders to regulate current characteristics. To be sure of the weld be sure of the governor!

THE PIERCE GOVERNOR COMPANY • 1633 OHIO AVENUE • ANDERSON, INDIANA

Pierce Governors

STANDARD SINCE 1913

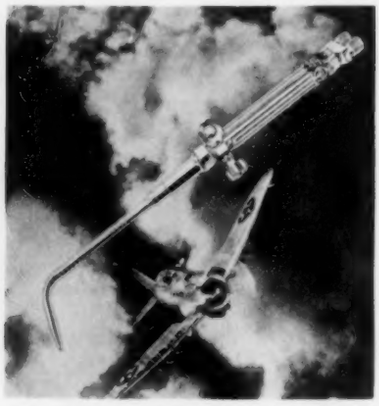
unit resting on the lower electrode. Pressing the control actuates the hydraulic welding gun, bringing the upper electrode down against the part to be welded, and initiating the weld cycle.

Features of the deep throat welder include elimination of frequently troublesome flexible shunts; positive hydraulic or air-hydraulic pressure at the electrodes; non-magnetic head construction, cutting induction losses; straight-line movement of the upper electrode; provision of non-flicker pressure switch; positive cooling circulation, etc. The lower arm is adjustable for height as in other Progressive welders.

The welders are available in standard capacities of 75 and 150 kv. Other capacities are available on special order.

AIRCRAFT WELDING TORCH

Exceptional balance for precision work, light weight of only seven ounces for tireless welding, convenient front-end valve wheels for one-hand flame adjustment, compactness to get around jigs and fixtures, and a fast, penetrating flame for sound and uniform welds are found in the design of the new Rego Aircraft Welding Torch for aircraft, automobile, sheet metal, tube and production welding up to $^1/_4$ in., National Cylinder Gas Company, 207 West Wacker Drive, Chicago, Illinois.

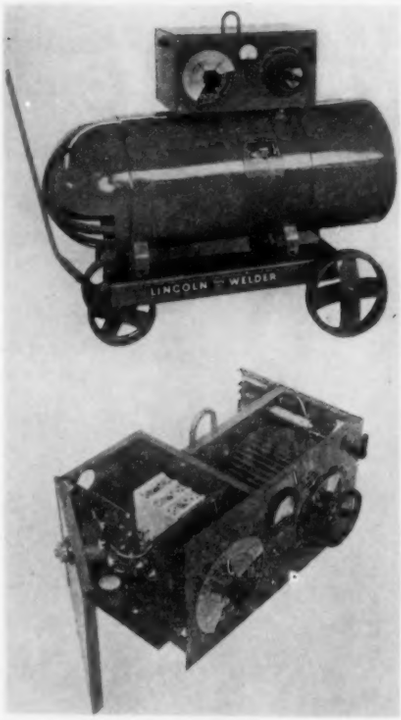


Long bend and short bend swaged tips of pure copper, with brass protectors to prevent damage to tip threads, are available in sizes 76, 72, 68, 62, 59, 55, 53 and 51 (drill size of orifice). Flame characteristics may be varied from short to long pointed, as each tip covers a relatively wide range of heat output.

A circular showing the Rego AC in actual size and actual color, exact dimensions of each of the 16 tips, as well as complete operating data (pressures, consumptions, metal thicknesses, etc.), is available and will be sent free upon request.

ARC WELDER CONTROL BOX

Further improvement in Dual Continuous Control for arc-welding machines, in the form of a new welder control box of advanced design and construction, is announced by The Lincoln Electric Company, Cleveland, Ohio.



New "Type G" Control Box Announced by The Lincoln Electric Co., Cleveland, Ohio, for Arc-Welding Machines. Figure 1 (Above) —the Box Mounted on 300-Ampere Portable Motor-Driven Welder and Fig. 2 (Below)— the Box Unmounted and Open Showing Arrangement and Parts

Enhancing the benefits of Dual Continuous Control, the new box, designated "Type G" (see accompanying Figs. 1 and 2), prevents accidental contact with live parts, increases accessibility, permits wiring with flexible or rigid conduit, or rubber-covered multiple-conductor cable and eliminates dangers from unintentional loosening of the lifting hook.

An important feature of the new box is the fact that there is a separate compartment for all a.c. circuits, including push button, and another separate one for d.c. terminals.

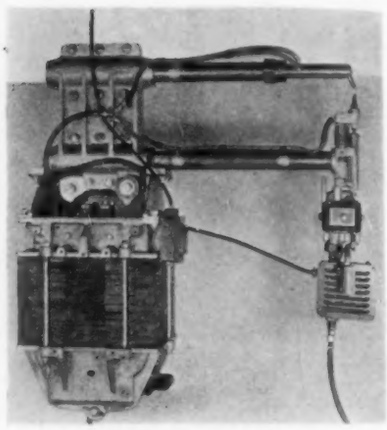
Both a.c. and d.c. compartments have a snap catch which holds the door in closed position. The a.c. compartment door also has screws for locking to prevent any unauthorized person from opening the compartment and touching live parts. The catch, however, holds the door in closed position in case the screws should accidentally or temporarily be left out of their proper places. On the d.c. compartment, the snap catch feature of the door makes the terminals readily accessible without the use of tools and, at the same time, provides a complete cover for the terminals when the door is closed.

An additional feature is a new lead clamp which prevents the bending or damage to output studs when the welder leads are accidentally jerked or pulled.

PORTABLE WELDING MACHINES

A line of "portable" welding machines, with built-in transformers designed for suspension from monorails, etc., has been announced by Progressive Welder Company, 3100 E. Outer Drive, Detroit. While they may be used for much of the work now done on pedestal welders, they have particular advantages in such applications as:

1. Spot welding of large units requiring clearance from the ground under the welding arms, or of heavy units.
2. Spot welding of parts on a conveyor.
3. Spot-welding assemblies in several jigs in one department, requiring movement of the welding equipment.
4. Pinch welding of spots not easily accessible with gun type welders due to throat limitations.
5. Jobs which can be handled most effectively by a unit suspended from a swinging or traveling crane.



In effect, the new welding machines are a cross between "pedestal" and gun welders. Like welding guns they may be moved or swung around to bring the gun to the work, reducing work handling. Like pedestal welders they have rigid arms with a high degree of throat depth, and the higher degree of efficiency going with the eliminating of secondary cables.

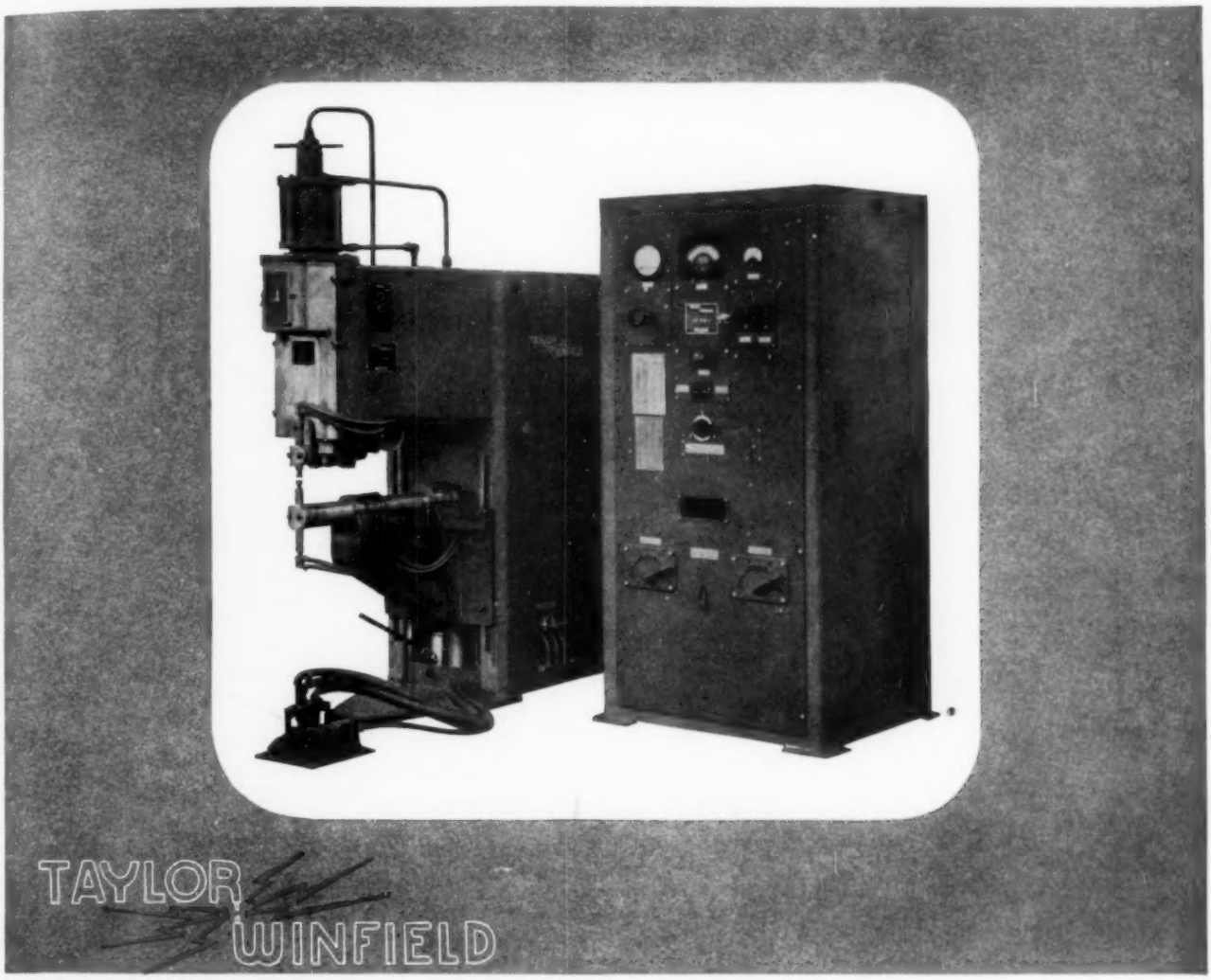
Lower in cost than pedestal welders, the new machines are obtainable in a complete range of sizes from 35 to 400 kva., and with arm lengths ranging up to a practical maximum of 36 inches of throat depth.

ABSORBENT SWEATBAND

A new lightweight absorbent sweatband, made of synthetic sponge, is announced by the American Optical Company, Southbridge, Mass. The sponge is $7^1/_2$-in. long, covers a generous width of brow. The sweatband can be sterilized, used again and again. It keeps sweat out of eyes and off goggles, thereby keeping vision clear so that foundrymen, welders and other workers on hot jobs won't get blindly into harm's way.

In connection with the announcement, the optical concern points out that time studies in a large foundry showed chippers and grinders spent 42 minutes per man per day mopping goggles and foreheads, a

SPOT WELDERS FOR AIRCRAFT



HI-WAVE

WELDERS

THESE ULTRA-MODERN MACHINES WILL BE IN OPERATION AT THIS YEAR'S NATIONAL METAL CONGRESS . . . BOOTH A-1

Improved standards in Spot-Weld Quality have been set by the new TAYLOR-WINFIELD Hi-Wave Welder with Roller Anti-Friction Head. Like other products of TAYLOR-WINFIELD origin, this unit receives the benefit of both design and construction under *one* responsibility.

With Bellows Air-lock, Retractable Stroke and improved Control Cabinets, the TAYLOR-WINFIELD Hi-Wave Welder is the most refined and completely developed spot welder available. *It is the first American Condenser Discharge Type Machine!* ... Complete details will be mailed upon application.

The TAYLOR WINFIELD Corporation

WARREN, OHIO, U.S.A.

MANUFACTURERS OF
ELECTRIC, BUTT
SPOT AND SEAM
WELDERS

TAYLOR-WINFIELD Welders are manufactured and sold in Canada by COMMONWEALTH ELECTRIC CORPORATION, LTD., Welland, Toronto and Montreal; and in Europe by AB. ASEA SVETSMASKINER, Stockholm, Sweden.

The Denton & Anderson Company – Cleveland, Chicago, Detroit. Other Representatives in principal cities of the U. S.

needless loss of time and definite proof that workers need the comfort and protection given by a reliable, truly absorbent sweatband. Also, as comfort is increased by wearing a sweatband, fatigue lessens and a man can do better, faster work.

Employment Service Bulletin

SERVICES AVAILABLE

A-416. Research Engineer Available. Age 56. Was Director of Research of an important wire company; Engineer Research and Tests, The Port of New York Authority; also formerly with the U. S. Bureau of Standards. Prefer vicinity New York or Philadelphia. Full information upon request.

A-417. Arc Welder with two years' experience wishes position where he can advance himself. Apprentice job acceptable. Completed College Technical entrance high school course majoring in drafting. Two-year College study and completed Hollup Welding School Course.

POSITIONS VACANT

V-102. Engineer, recent graduate in metallurgical engineering, to serve as laboratory assistant on metallic arc welding research, 2 to 3 years' experience on code welding desired. State age, education and experience. Replies held in strict confidence.

V-103. Welding Salesman wanted. Distributor of nationally known lines of welding equipment and supplies has opening for experienced welding salesman. Give complete details of past experience. Address Machinery and Welder Corporation, 700 South Spring Ave., St. Louis, Mo.

SECTION ACTIVITIES

BIRMINGHAM

The following officers and executive committee members were elected by the Birmingham Section for 1941–42.

Chairman, F. E. McAtee, Chicago Bridge & Iron Co.; *Vice-Chairman*, C. C. Pinckney, Birmingham Boiler & Eng. Co.; *Secretary-Treasurer*, W. L. Poole, Air Reduction Sales Co. *Executive Committee:* W. C. Sleeman, R. E. Jones, Sr., Paul Wright, Julian W. Adams, C. R. Tinsley, E. W. Braun, E. H. Anchors, R. C. Palmer.

CHICAGO

Dr. W. A. Pearl, Director of Development, Whiting Corp., presented an illustrated talk on the subject of "Metallurgical Aspects of Welding" at the September 19th meeting. The presentation was of special interest to engineers, designers and fabricators who were familiarized with the composition and structure of the steel, how the steel is affected by heat in welding, and the way in which metallurgy can be used to control the welding process.

An interesting movie was shown at the start of the meeting.

CLEVELAND

The Cleveland Section is to meet this year in the new home of The Cleveland Engineering Society located at 2136 East 19th St. The auditorium is large, beautifully furnished and with a seating capacity of 500. Dinners will be served in the main dining room located on the first floor.

The speaker for the first meeting of the season, October 8th, was Mr. Wm. Stout of Stout Skyways, Inc., Detroit, who delivered a talk on "The Future of Aviation and Its Relation to Welding." Mr. Stout formerly was with the Ford Motor Company. The dinner speaker was Major J. Berry, Supt. of Cleveland Air Port, who gave a talk on "Cleveland Aviation."

The following are the officers and chairmen of committees of the Section for the 1941–42 season:

Chairman, J. F. Maine; *Secretary*, A. L. Pfeil; *Vice-Chairman*, R. J. Kriz; Intersociety Coordinating Committee, A. F. Davis, chairman; Nomination Committee, E. T. Scott, chairman; Publicity, C. T. Elder, chairman; Reception and Dinner Committee, Jim Brow, chairman; Sponsors, Thomas Lawless, chairman; Properties Committee, J. Calvin Wyss, chairman; Membership, Ray Metzger, chairman; Program, R. J. Krizz, chairman; Educational, Gordon B. Carson, chairman; Code Committee, E. R. Benedict, chairman; Resistance Welding, J. E. Mallett, chairman; Arc Welding, R. P. Tarbell, chairman; Gas Welding, E. B. Pederson, chairman; Affiliates, Joseph Haprian, chairman; Fabricators Committee, J. T. Lewis, chairman; Engineering, Robert Kincaid, chairman; Metallurgy, J. C. Hodge, chairman; Marine Committee, L. C. Host, chairman; Railway, Walter Davis, chairman; Symposium, Joseph Wagner, chairman.

DETROIT

The September meeting of this Section was held on the 5th at the Detroit-Leland Hotel with an attendance of over two hundred. Dr. A. V. DeForest, Professor of Physics, Massachusetts Institute of Technology, spoke on "The Principles of Magnaflux Inspection." This talk was very well received as was also an American Lines film, "Flagships of the Air." Refreshments were served after the meeting. Members of the Detroit Section of A. S. T. M. were extended a special invitation to attend the meeting.

The November meeting will be held on the 7th at which time Dr. W. G. Theisinger of Lukens Steel Co. will speak on "Heat and Mechanical Stresses in Welding."

The December meeting on the 5th is scheduled to be an "Information Please" type of meeting, with a group of experts on hand to take care of questions.

KANSAS CITY

The Kansas City, Mo., Section held an open house meeting and round-table discussion as their first meeting of the season on September 22nd. Pictures and short talks were given by Section members.

Building activities during the summer have been a Remington Arms plant and North American Aviation Bomber plant; both places doing welding on a large scale.

NEW YORK

The activities of the New York Section for the 1941–42 season were inaugurated Tuesday evening, September 9th, by a meeting held in the large auditorium at the Engineering Societies' Building. The session, ably arranged by the Program Committee directed by Mr. J. G. Magrath, chairman, was given over to the subject of Aircraft. As somewhat of an innovation, one of the papers presented at the meeting was technical in scope while the other was more popular in its appeal. The first paper was on the subject of "Welding of Steel Aircraft Tubing," and was presented by Mr. Arthur J. Williamson, chief metallurgist of Summerill Tubing Company, Bridgeport, Pa. Mr. Ralph S. Damon, president of Republic Aviation Corporation, Farmingdale, Long Island, N. Y., then talked on the subject of "Air Transportation." An added feature was the presentation of two sound motion

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. . . *For many hard surfacing operations,* torch application is preferable. And here too the wide range of VICTOR welding torches demonstrates the fact that "It costs less to own and operate VICTOR Welding and Cutting Apparatus."

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pictures, "Flagships on Parade" and "The Airline Stewardess," presented by Mr. C. R. Speers and Mr. H. J. Lyall, sales manager and assistant sales manager, respectively, of the New York Office of American Airlines, Inc. Mr. Leslie B. Neville, editor of *Aviation*, McGraw-Hill Publishing Company, served as chairman of the meeting.

Prior to the general meeting, there was a meeting of the Executive Committee of this Section, under the leadership of Mr. E. V. David, chairman. At that meeting, the reports of the various subcommittees indicated that plans were well under way for a successful season.

NORTHERN NEW JERSEY

An even gross of members and guests turned out for the Second Annual Outing of the Northern New Jersey Section at Angele's Grove, Union, N. J., on Saturday afternoon, September 6th. In spite of weather forecasts to the contrary, the day opened fair and stayed that way until closing time at the lunch counter. Several members reported that there would have been still greater attendance from their organizations except for the fact that so many men were working Saturday afternoons on the defense program. The attendance prize was won easily by a delegation from the Bayonne refinery of Standard Oil, who arrived thirty strong in a chartered bus. This delegation also claimed the softball championship. The whole plan of the Outing was the same as for the first Outing which was held last year. Mr. G. C. Holder, chairman of the Outing Committee, was complimented for the highly satisfactory arrangements which gave the Section an opportunity for an afternoon of sociability and recreation prior to the opening of the new program of meetings.

The Officers and the Executive Committee and other standing committees of the Section have been meeting frequently during the summer months and making constructive plans for Section activity during the winter season. The Program Committee has practically completed its program arrangements for the coming year and will soon have a printed program schedule ready for distribution. Mr. Alexander Kidd, of the M. W. Kellogg Company, is chairman of the Program Committee. The Educational Committee, under the chairmanship of Mr. M. F. Sheely of the Standard Oil Development Company, is making plans for a lecture course during the winter season. A complete announcement will be available as soon as final arrangements have been checked.

The regular Section meeting was held on September 16th. Dinner in the Starlight Terrace of the Essex House, Newark, preceded the meeting, which was held in the Oxford Room. Mr. Fred G. Outcalt, Engineer, The Linde Air Products Co., presented an informal illustrated talk on "The Unionmelt Automatic Electric Welding process." Discussion followed in which members and guests participated. A movie, "The Golden Gate Bridge," was presented through the courtesy of John A. Roebling's Sons Co. of Trenton. This was a remarkably spectacular and educational film.

The October meeting will be held on the 28th to avoid conflict with the Annual Meeting of the SOCIETY.

OKLAHOMA CITY

Dr. R. H. Aborn of the Research Laboratory, United States Steel Corp., will speak before the four Southwestern Sections—Kansas City, Wichita, Tulsa and Oklahoma City—on consecutive nights starting January 6th. Dr. Aborn's subject will be "Metallurgy in Ferrous Welding." The programs for the above sections are being arranged jointly and will soon be completed.

The University of Oklahoma at Norman will offer courses in metallurgical engineering this fall for the first time. New equipment has been purchased and is installed in a special laboratory.

PEORIA

The first meeting of the season was held on October 4th and was addressed by Mr. W. B. Browning of The Linde Air Products Co., who spoke on "Machine Flame Cutting." November 5th will be a joint meeting of the local chapter of the American Society for Metals and the Peoria Section; the guest speaker will be Colonel W. J. Crook of the Rock Island Arsenal. The December meeting will be held on the 3rd. The annual business meeting will be held on January 7th without a guest speaker. Mr. A. W. Harris, Chief Engineer in charge of Maintenance, Western Cartridge Co., will be the speaker at the February 4th meeting. The March meeting will be held on the 4th. Mr. E. R. Fish of the Hartford Steam Boiler Inspection and Insurance Company will speak at the April 1st meeting. May 6th is the date for the May meeting.

PHILADELPHIA

The September meeting of this Section was held on the 15th. "Welding of Special Steels Used in Major Defense Operations" was the subject presented by Mr. R. D. Thomas of the Arcos Corporation.

The Annual Meeting of the Society will be held in Philadelphia in October, hence there will be no local Section meeting.

The following is the program for the meetings for the remainder of the season.

November 17, 1941—Symposium on Codes. Speakers: H. O. Hill—"A. P. I. Code;" A. G. Bissell—"Navy Specifications;" G. F. Jenks—"Army Specifications;" Commdr. Trexel—"Structural Codes."

December 15, 1941—"Resistance Welding." Introduction: W. L. Ramsay, N. Y. Shipbldg. Corp. Speaker: R. T. Gillette, General Electric Co. Discussion: A. B. House and Oscar Fredericks.

January 19, 1942—"Arc Welding Electrodes." Speaker: J. W. Miller, Reid-Avery Co. Discussion: R. D. Thomas.

February 16, 1942—"Welding's Part in Fabrication of Railroad Equipment to Facilitate Rapid Movement of Defense Materials." (Probably will take place in the Franklin Institute Auditorium.)

March 16, 1942—"More Important Fields for Gas Welding."

April 20, 1942—"Structural Welding."

May 18, 1942—"The Welding of High-Pressure Piping." Speaker: Mr. Bela Ronay, U. S. Naval Experiment Station.

ST. LOUIS

The first inspection trip through the Laclede Gas & Light Co. Coke Plant was held by the St. Louis Section on Friday September 12th. Members and guests were given an opportunity to see a typical gas plant in full operation. Ample time was allowed for individual inspection.

TULSA

A joint meeting of the Tulsa, Oklahoma City, Wichita and Kansas City Sections was held at Wichita on June 12th, at which time the program for the 1941-42 season was outlined and as soon as the program is definite it will be published in the JOURNAL.

YORK-CENTRAL PA.

Arrangements have been made for the following program and speakers for the 1941-42 season.

October—As many of membership as possible are to attend in a body for one day the Annual Meeting of the Society in Philadelphia. A business meeting, election of officers and a movie will be the program for the Section this month.

November—"Welding of Monel Metal and Clad Steels," by F. G. Flocke, International Nickel Co.

December—"Procedure Control and Qualification of Operators," by O. T. Barnett, Metal & Thermit Corp.

Jan. 1942—"Welding of Alloys," by E. C. Chapman, Combustion Eng. Co.

February—"Stainless Steel," by R. D. Thomas, Arcos Corp.

March—Annual Dinner. Mr. K. L. Hansen, Harnischfeger Corp.

April—"Welding of Ferrous Metals," by R. H. Aborn, U. S. Steel Corp.

May—A. J. Raymo, Baldwin-Southwark. Subject to be announced.

The dates will be worked out later to suit the convenience of the speakers.

USED WELDING HANDBOOKS WANTED

We have an urgent request from Professor G. B. Carson of Case School of Applied Science, Cleveland, Ohio, for copies of the 1938 edition of the Welding Handbook. Any members, desiring to sell a handbook which is in good condition, may communicate directly with Professor Carson, stating the price wanted.